PB80-219520

Thirty-day Field Tests of Industrial Boilers Site 4 Coal-fired Spreader Stoker

KVB, Inc.
Irvine, CA

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

Apr 80

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA-600/7-80-085d

2.

3. RECIPIENT'S ACCESSION NO.
PB80 219520

4. TITLE AND SUBTITLE
Thirty-day Field Tests of Industrial Boilers: Site 4--Coal-fired Spreader Stoker

5. REPORT DATE
April 1980

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
W.A. Carter and J.R. Hart

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
KVB, Inc.
P.O. Box 19518
Irvine, California 92714

10. PROGRAM ELEMENT NO.
EHE624

11. CONTRACT/GRANT NO.
68-02-2645, Task 4

12. SPONSORING AGENCY NAME AND ADDRESS
EPA, Office of Research and Development
Industrial Environmental Research Laboratory
Research Triangle Park, NC 27711

13. TYPE OF REPORT AND PERIOD COVERED
Task Final; 3/79-3/80

14. SPONSORING AGENCY CODE
EPA/600/13

15. SUPPLEMENTARY NOTES IERL-RTP project officer is Robert E. Hall, Mail Drop 65, 919/541-2477.

16. ABSTRACT

This is a final report for a test program to evaluate the long-term effectiveness of combustion modifications on industrial boilers. Previous short-term tests had been performed on industrial boilers to determine the effect of combustion modifications on such air pollutant emissions as NOx, SOx, CO, HC, and particulate. The objective of this program was to determine if the combustion modification techniques which were effective for the short-term tests are feasible for longer periods. The report gives results of a 30-day field test of a 38.1 MW (130,000 lb steam/hr) output coal-fired spreader stoker. Low excess air was used to control NOx emissions. Results indicate that low excess air firing is an effective long-term NOx control for spreader stokers. The as-found NOx concentration was 240 ng/J (409 ppm at 3% O2, dry) with the boiler load at 80% of design capacity. Firing in the low excess air mode reduced the as-found condition by about 19%. Low excess air firing also increased efficiency by about 1.2% and decreased particulates by about 22%.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Nitrogen Oxides	Pollution Control	13B	
Boilers	Carbon Monoxide	Stationary Sources	13A	
Coal	Hydrocarbons	Industrial Boilers	21D	07C
Combustion	Dust	Combustion Modification	21B	11G
Field Tests		Spreader Stokers	14B	
Stokers		Low Excess Air		
Sulfur Oxides		Particulate	07B	

18. DISTRIBUTION STATEMENT
Release to Public

19. SECURITY CLASS *(This Report)*
Unclassified

20. SECURITY CLASS *(This page)*
Unclassified

21. NO. OF PAGES

22. PRICE

PB80-219520

United States
Environmental Protection
Agency

Industrial Environmental Research
Laboratory
Research Triangle Park NC 27711

EPA-600/7-80-085d
April 1980

EPA

Thirty-day Field Tests of Industrial Boilers:
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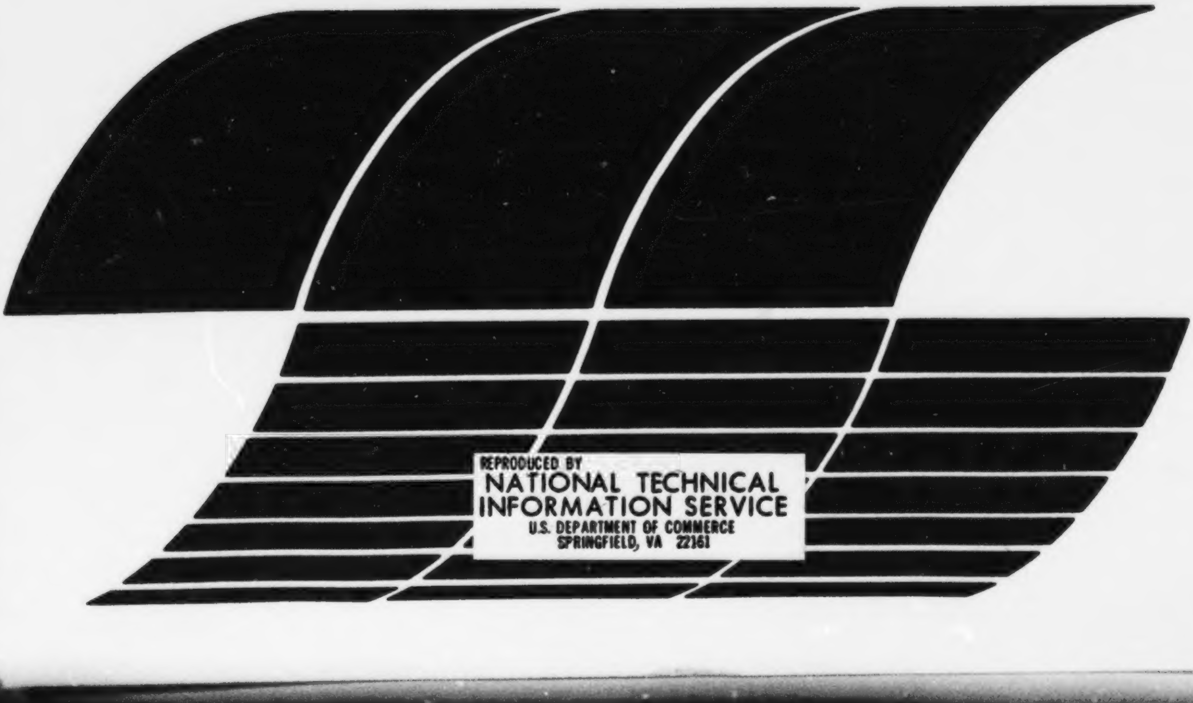
Interagency
Energy/Environment
R&D Program Report



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EPA-600/7-80-085d

April 1980

Thirty-day Field Tests of Industrial Boilers:

Site 4 — Coal-fired Spreader Stoker

by

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Contract No. 68-02-2645
Task No. 4
Program Element No. EHE624

EPA Project Officer: Robert E. Hall

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Prepared for

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Washington, DC 20460

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ABSTRACT

This is a final report on a test program to evaluate the long-term effectiveness of combustion modifications on industrial boilers. During previous programs short-term tests have been performed on industrial boilers to determine the effect of combustion modifications on air pollutant emissions such as NOx, SOx, CO, HC, and particulate. The objective of this program was to determine whether the combustion modification techniques which were effective for short-duration tests are feasible for a longer period. This report presents results of a 30-day field test of a 38.1 MW output (130,000 lb steam/hr) coal-fired spreader stoker. The NOx control technology employed on this unit was low excess air and staged combustion air. The results indicate that low excess air firing is an effective long-term NO_x control technique for spreader stokers, while the use of staged combustion air by overfire air adjustment is not. The as-found concentration of NO_x was 240 ng/J (409 ppm at 3% O_2, dry) with the boiler load at 80% of design capacity. Firing in the low excess air modes resulted in a reduction of approximately 19% from the as-found condition. Low excess air firing also resulted in an increase in efficiency of approximately 1.2%, and also a decrease in particulates of about 22%.

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SECTION 1.0

SUMMARY

1.1 OBJECTIVE AND SCOPE

The objective of this field test was to determine whether combustion modification techniques which demonstrated reductions on air pollutant emission during short-term tests are feasible for longer periods. In addition, boiler performance and reliability were monitored. The combustion modifications have previously been shown to be effective on industrial boilers (Refs. 1, 2, 3).

The program scope provides for 30-day field tests of a total of seven industrial boilers with design capacities ranging from 14.65 to 73.25 MW output (50,000 to 250,000 lb steam/hr). Fuels to be burned include natural gas, light oil, residual oil, and coal. This final report is for a 38.1 MW output (130,000 lb steam/hr) coal fired stoker using low excess air (LEA) and staged combustion air (SCA) by means of overfire air adjustments as the emission control technology.

During the test period, continuous monitor certification tests were performed concurrently with low NOx testing. Emissions measured were particulate, NO, CO_2, and O_2. Boiler efficiency was measured several times during the program to determine the effect of combustion modification on boiler efficiency.

This is a final report on the 30-day test which documents the test equipment, summarizes the test data, and discusses the data in relation to the control technology employed for this type of boiler.

1.2 RESULTS

A coal stoker using LEA as the control technology was selected for this field test. A survey of previous tests on coal-fired boilers was conducted to determine if a boiler was available which would provide low-NO_x operation using the desired NO_x control technology. Included in the survey were boilers tested under previous EPA programs (Refs. 1, 2, and 3) as well as current programs. It was desirable to select a unit which had been tested previously in order to know its capability for low-NO_x operation, minimize set-up time, and eliminate the need for extensive modification testing.

The boiler tested at Site 4 was selected on the basis that previous testing had been performed by KVB and the unit had shown a capability of operating under low-NO_x conditions. Although the boiler selected for testing was built in 1960 it is representative of the majority of coal-fired industrial boilers sold today. During a previous EPA-sponsored program (Ref. 1) a boiler survey and analysis was performed to determine the population and distribution of coal-fired industrial sized boilers. This study showed that spreader stokers account nationally for about 50% of the units sold during the nine-year period from 1965 to 1964, followed by 20% for other types of coal firing, 13% for overfed stokers, 9% for pulverized, and 7% for underfed stokers.

After selection of the test site, a continuous monitor was shipped to the site and installed. The next task was to perform the certification tests as outlined in Performance Specification 2 and 3, 40 CFR60, Appendix B (Appendix D of this document).

Following the monitor certification, the 30-day field test was conducted. The test was performed according to "Plan for Performing Source Evaluation Tests in Support of NSPS for Industrial Boilers." Emissions of NO, CO_2, and O_2 were monitored continuously. Particulate measurements were made in triplicate at the start and conclusion of the test period. In addition, triplicate particulate measurements were made in the as-found condition. Measurements of polycyclic organic matter were made in both the modified and unmodified conditions.

The results of the 30-day test are discussed in detail in Section 3.0. A summary of the 24-hour averages of gaseous emissions is presented in Table 1-1. The data presented in this table were recorded by a technician on an hourly basis each day and are in addition to the continuous strip chart recordings. An analysis of the field test data was prepared. A log-probability plot of 24-hour averages is presented in Figure 1-1. The mean value for the NO is 211 ng/J with a geometric dispersion of 1.06. The NO emissions were less than 245 ng/J 99% of the time.

1.3 CONCLUSIONS

Based on the results of this 30-day field test, several important conclusions can be drawn:

1. LEA is an effective NO_x control technology for coal-fired spreader stokers. The LEA condition was maintained for 30 days with an average NO emission level of 211 ng/J (360 ppm @ 3% O_2, dry) with the boiler load at 22.3 MW thermal output (76,000 lb steam/hour). At the same load the baseline NO emissions are 229 ng/J (390 ppm). At a boiler load of 27.5 MW output (94,000 lb steam/hr) the NO emissions were 240 ng/J (409 ppm @ 3% O_2, dry) in the LEA condition.
2. Staged combustion air had virtually no effect on NO emissions in this coal-fired spreader stoker. Extensive variant overfire air biasing modes were implemented but produced little change in the NO emissions.
3. Boiler operation in the LEA mode presented no reliability of functional problems. The LEA mode can be maintained for extended periods provided adequate instrumentation and display are provided. An indoctrination and training period for operators is recommeded.
4. Operation of the boiler in the LEA mode resulted in 22% lower particulate emissions than for normal operation. Normal operation produced 626 ng/J (1.46 lb/10^6 Btu) of particulate emissions. Operation in the LEA mode resulted in average particulate emissions of 491 ng/J (1.14 lb/10^6 Btu). Additional testing would be required to optimize the boiler for both NO_x and particulate emissions and efficiency.

TABLE 1-1. 24-HOUR AVERAGES OF GASEOUS EMISSIONS

```
**************************************************************
**                       24 HOUR DATA                       **
**                DRY STACK GAS CONCENTRATION               **
**                                                          **
**                         O2     CO2     NO     NO     NO  **
**                 LOAD   VOL%   VOL%   PPMV   PPMV   NG/J  **
**   DATE   TIME   MWTH   MEAS   MEAS   MEAS   3%O2         **
**************************************************************
** 8/11/79         24.6    9.3   10.1   252.   390.   229.  **
** 8/12/79         19.1   10.8    8.6   219.   389.   229.  **
** 8/13/79         21.7   10.0    9.6   225.   371.   218.  **
** 8/14/79         21.4   10.2    9.5   204.   341.   200.  **
** 8/15/79         21.2   10.5    9.2   224.   384.   225.  **
** 8/16/79         21.7    9.9    9.6   221.   360.   211.  **
** 8/17/79         23.0    9.5    9.7   230.   362.   212.  **
** 8/18/79         22.0    9.9    9.4   227.   369.   217.  **
** 8/19/79         18.3   10.8    8.3   222.   393.   231.  **
** 8/20/79         24.5    9.4    9.8   241.   374.   219.  **
** 8/21/79         24.0    9.2   10.0   220.   338.   198.  **
** 8/22/79         23.5    9.5    9.8   235.   368.   216.  **
** 8/23/79         21.7   10.4    8.9   206.   350.   206.  **
** 8/24/79         21.5    9.9    9.8   221.   358.   210.  **
** 8/25/79         19.5   10.5    9.1   208.   356.   209.  **
** 8/26/79         18.4   10.6    8.7   195.   340.   199.  **
** 8/27/79         22.9    9.9    9.6   231.   374.   220.  **
** 8/28/79         24.1    9.3    9.9   225.   348.   204.  **
** 8/29/79         25.9    9.1   10.4   245.   372.   218.  **
** 8/30/79         24.8    9.4   10.1   235.   368.   216.  **
** 8/31/79         26.8    8.7   10.7   239.   350.   206.  **
** 9/ 1/79         22.7    9.7    9.9   217.   348.   204.
** 9/ 2/79         18.5   10.5    9.1   207.   355.   208.  **
** 9/ 3/79         19.1   10.3    9.5   198.   333.   196.  **
** 9/ 4/79         27.2    8.8   10.8   238.   353.   207.  **
** 9/ 5/79         25.7    9.1   10.4   239.   363.   213.  **
** 9/ 6/79         23.4    9.7    9.9   223.   355.   208.  **
** 9/ 7/79         22.2    9.7    9.7   224.   358.   210.  **
** 9/ 8/79         19.8   10.1    9.1   231.   385.   226.  **
** 9/ 9/79         19.1   10.2    9.1   244.   407.   239.  **
** 9/10/79         23.8    9.4   10.1   241.   374.   220.  **
** 9/11/79         22.8    8.8   10.4   257.   382.   224.  **
** 9/12/79           .0   10.3    8.5   214.   359.   211.  **
**************************************************************
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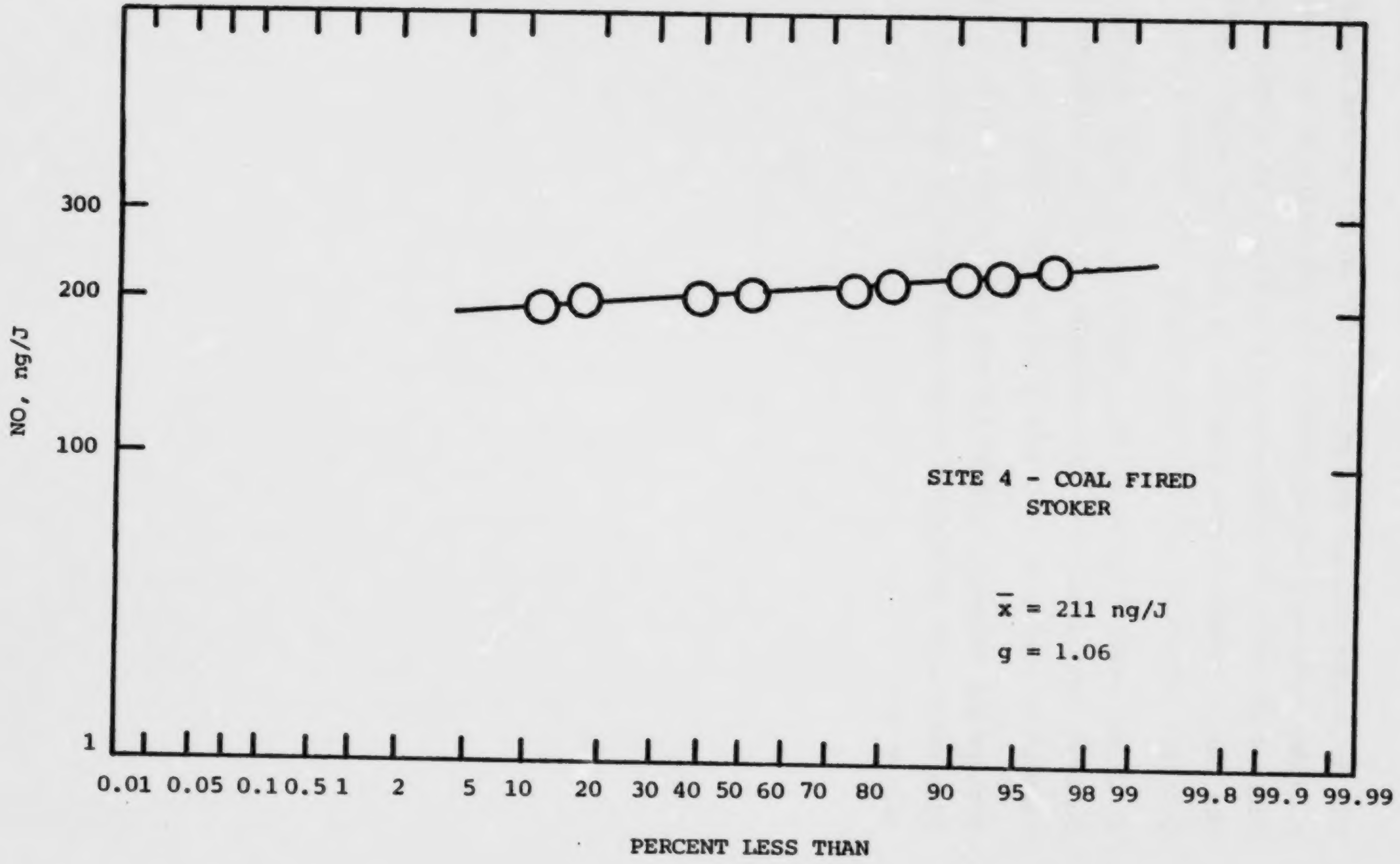

Figure 1-1. NO Emissions Site 4 Coal-Fired Spreader-Stoker.

5. The continuous monitor system utilizing an extractive sample system provided accurate, reliabile data for the entire 30-day test period. Daily calibration of instruments is necessary as is maintenance on the sample system. Probe plugging is a problem which requires periodic inspection and maintenance with coal-fired units.

6. It is extremely unusual for an industrial boiler to operate at a constant load condition. Any effective control technology must be capable of operation over fairly large load changes.

7. Stokers may decrease both NO and particulate emissions at the same time while also increasing boiler efficiency by operating with low excess air.

SECTION 2.0

INSTRUMENTATION AND PROCEDURES

This section presents a description of the instrumentation used to measure the gaseous and particulate emissions, the test procedures, and techniques for certifying the continuous monitor and a description of the boiler tested.

2.1 EMISSIONS MEASUREMENT INSTRUMENTATION

The emissions measurements were made using a continuous monitor fabricated by KVB for this program. The analytical instrumentation and sample handling equipment are contained in a cabinet 1.2 m wide x 0.76 m deep x 183 m high (48"W x 30"D x 72"H). A photograph of the continuous monitor is shown in Figure 2-1. Gaseous emission measurements were made with the analytical instruments listed in Table 2-1.

Total particulate measurements were made using an EPA Method 5 sampling train manufactured by Western Precipitation Division of Joy Manufacturing Company. Samples for measurement of polycyclic organic matter (POM) were obtained using an XAD-2 module supplied by Battelle Columbus Laboratories. These modules were returned to Battelle for analysis following the test.

2.1.1 Gaseous Emissions

The continuous monitor is equipped with analytical instruments to measure concentrations of NO, CO, CO_2, and O_2. The sample gas is delivered to the analyzers at the proper condition and flow rate through the sampling and conditioning system shown schematically in Figure 2-2. A probe with a 0.7-micrometer sintered stainless steel filter was installed in the stack to

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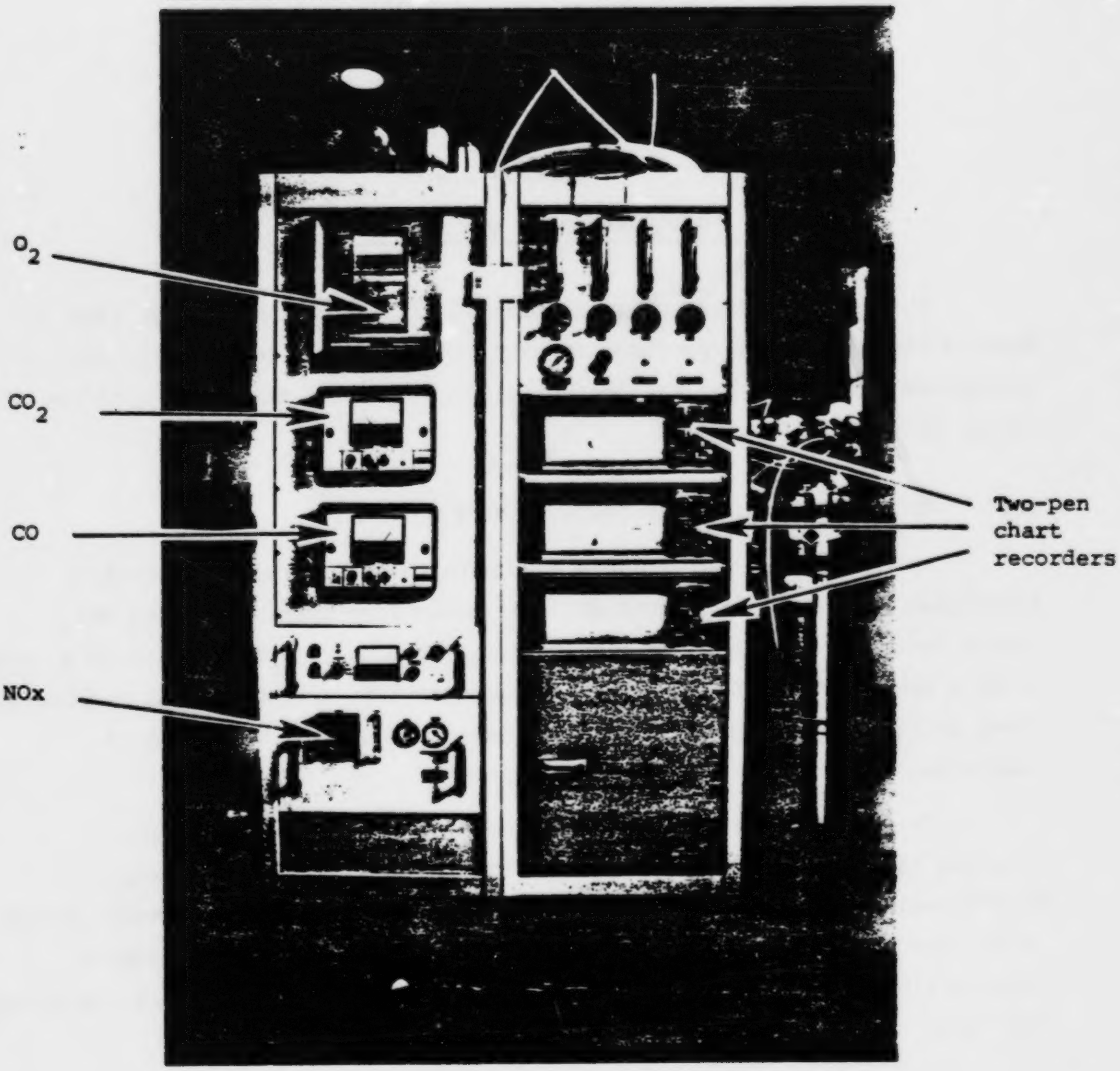
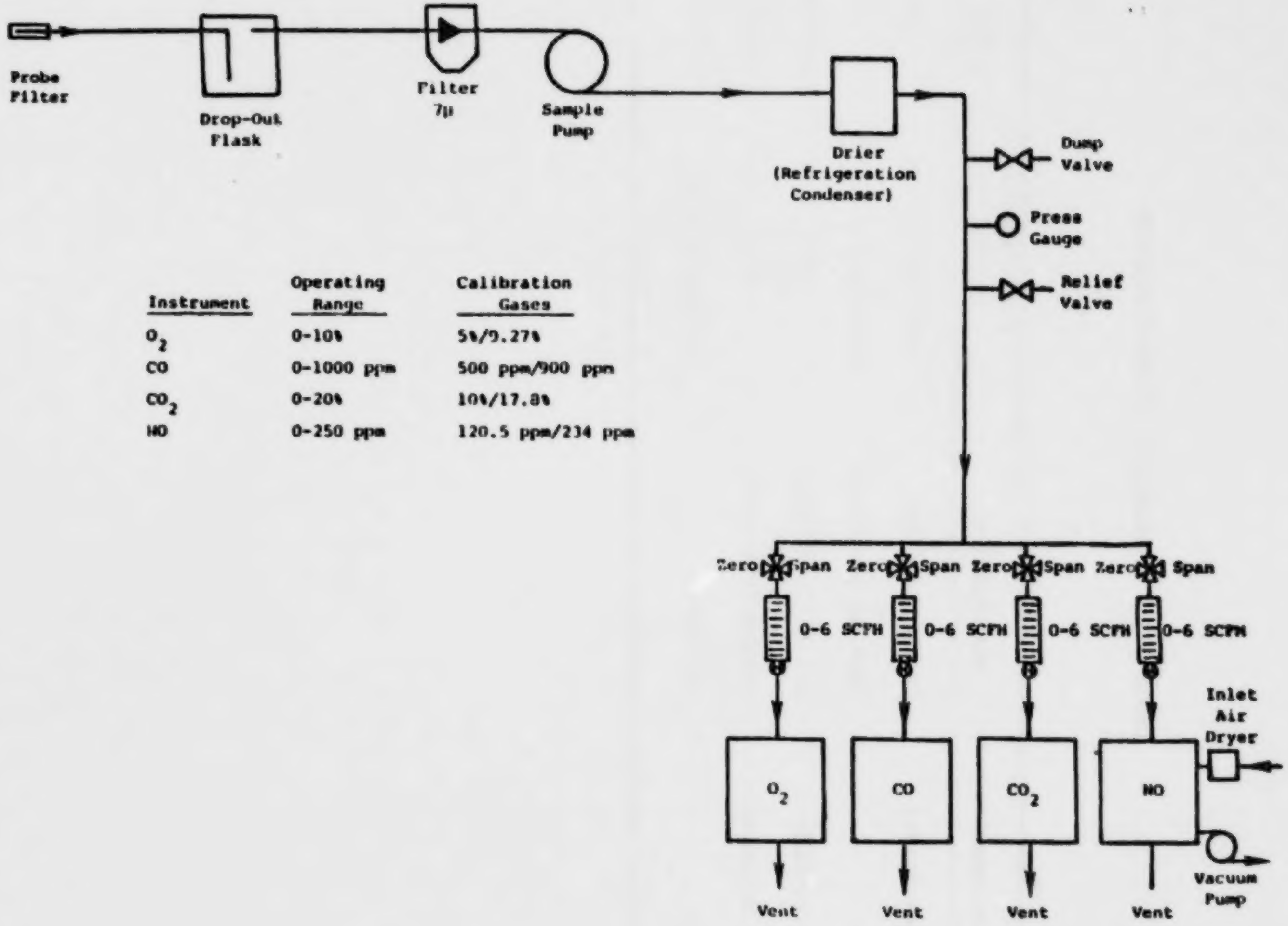


Figure 2-1. Photograph of KVB continuous monitor for measuring gaseous emissions.

TABLE 2-1. ANALYTICAL INSTRUMENTATION

Emission Species	Manufacturer	Measurement Method	Model No.
Nitrogen Oxides	Thermo Electron	Chemiluminescent	10A
Oxygen	Beckman Instrument	Polarographic	742
Carbon Dioxide	Horiba Instrument	NDIR	PIR-2000
Carbon Monoxide	Horiba Instrument	NDIR	PIR-2000
Opacity	Dynatron	Transmissometer	1100



Instrument	Operating Range	Calibration Gases
O_2	0-10%	5%/9.27%
CO	0-1000 ppm	500 ppm/900 ppm
CO_2	0-20%	10%/17.8%
NO	0-250 ppm	120.5 ppm/234 ppm

Figure 2-2. Schematic of continuous monitor sampling and conditioning system.

sample the flue gas. The following paragraphs describe the analytical instrumentation.

A. Nitrogen Oxides--

The oxides of nitrogen monitoring instrument used was a Thermo Electron chemiluminescent nitric oxide analyzer. The operational basis of the instrument is the chemiluminescent reaction of NO and O_3 to form NO_2 in an excited state. Light emission results when excited NO_2 molecules revert to their ground state. The resulting chemiluminescence is monitored through an optical filter by a high sensitivity photomultiplier tube, the output of which is electronically processed so it is linearly proportional to the NO concentration.

Air for the ozonator is drawn from ambient through an air dryer and a 10-micrometer filter element. Flow control for the instrument is accomplished by means of a small bellows pump mounted on the vent of the instrument downstream of a separator which insures that no water collects in the pump.

The basic analyzer is sensitive only to NO molecules. To measure NO_x (i.e., NO + NO_2), the NO_2 is first converted to NO. This is accomplished by a converter which is included with the analyzer. The conversion occurs as the gas passes through a thermally insulated, resistance heated, stainless steel coil. With the application of heat, NO_2 molecules in the sample gas are reduced to NO molecules, and the analyzer then reads NO_x. NO_2 is obtained by the difference in readings obtained with and without the converter in operation.

Specifications

Accuracy: 1% of full scale
Span drift: ± 1% of full scale in 24 hours
Zero drift: ± 1 ppm in 24 hours
Power Requirements: 115 ± 10V, 60 Hz, 1000 watts
Response: 90% of F.S. in 1 sec (NO_x mode); 0.7 sec (NO mode)
Output: 4-20 ma
Sensitivity: 0.5 ppm

Linearity: ± 1% of full scale

Vacuum detector operation

Range: 2.5, 10,25, 100, 250, 1000, 2500, 20,000 ppm F.S.

Only the NO concentration was measured during this program. Because of the added complexity of heated sample lines and controllers necessary for measuring NO_2 and the small percentage of NO_2 in the flue gas, based on previous tests (Ref. 1, 2 and 3) EPA decided that only NO measurement was necessary. Therefore, an unheated sample line was installed, and the moisture was removed from the sample gas by a dropout flask and a refrigerated condenser.

B. Carbon Monoxide and Carbon Dioxide--

Carbon monoxide (CO) and carbon dioxide (CO_2) concentrations were measured by Horiba Instruments PTI-2000 short-path-length nondispersive infrared analyzers. These instruments measure the differential in infrared energy absorbed from energy beams passed through a reference cell (containing a gas selected to have minimal absorption of infrared energy in the wave length absorbed by the gas component of interest) and a sample cell through which the sample gas flows continuously. The differential absorption appears as a reading on a scale of zero to 100% and is then related to the concentration of the species of interest by calibration curves supplied with the instrument. A linearizer was supplied with the CO analyzer to provide a linear output over the range of interest. The operating ranges for the CO analyzer are zero to 500, zero to 1000, and zero to 2000 ppm, and the ranges for the CO_2 analyzer are zero to 5, zero to 10, and zero to 20%.

Specifications

Accuracy: 1% of full scale

Repeatability: ± 0.5% of full scale

Zero drift: ± 1% of full scale in 24 hours

Span drift: ± 1% of full scale in 24 hours

Response time: selectable - 90% of full scale in 0.5, 1.2, 3, or 5 seconds

Power Requirements: 115 VAC ± 10%, 60 Hz
Warm up time: 30 minutes
Output: 0-10 MV

C. Oxygen--

A Beckman Model 742 oxygen analyzer was used to continuously determine the oxygen content of the flue gas sample. The oxygen measuring element contains a silver anode and gold cathode that are protected from the sample by a thin membrane of Teflon. An aqueous KCL solution is retained in the sensor by the membrane and serves as an electrolytic agent. As Teflon is permeable to gasses,oxygen will diffuse from the sample to the cathode in the following oxidation-reduction reaction:

Cathode reaction: $O_2 + 2H_2O + 4e \rightarrow 4OH$
Anode reaction: $4Ag + 4Cl \rightarrow 4AgCl + 4e$

With an applied potential between the cathode and anode, oxygen will be reduced at the cathode causing a current to flow. The magnitude of this current is proportional to the partial pressure of oxygen present in the sample. The instrument has operating ranges of zero to 1%, zero to 10%, and zero to 25% oxygen.

Specifications

Accuracy: ± 1% of full scale or ± 0.05% O_2 whichever is greater
Sensor stability: ± 1% of full scale per 24 hours
Response time: 90% in 20 seconds
Output: 0-10 MV
Power requirement: 120 1 10 VAC, 60 Hz

2.1.2 Particulate Emissions

Particulate samples were taken from two ports on the side of the duct located 90° from the gaseous emission sample port. The samples were taken using a Joy Manufacturing Company portable effluent sampler. This system, which meets the EPA design specifications for Test Method 5 (Determination of Particulate Emissions from Stationary Sources, Federal Register, Volume 42, No. 160, page 41754, August 18, 1977) is used to perform both the initial velocity traverse and the particulate sample collection. Dry particulates are collected in a heated case that contains, first, a cyclone to separate particles larger than 5 micrometers and, second, a 100-mm glass-fiber filter for retention of particles down to 0.3 micrometers. Condensible particulates are collected in a train of four Greenburg-Smith impingers in a chilled water bath.

2.1.3 Polycyclic Organic Matter (POM) Emissions

Particulate and gaseous samples for analysis of polycyclic organic matter were taken at the sample port used for Method 5 particulate tests. The sampling system is a modified Method 5 sampling train developed by Battelle Columbus Laboratories. A combination of conventional filtration with collection of organic vapors by means of a high surface area polymeric adsorbent (XAD-2) proved highly efficient for collection of all but the more volatile organic species. The modified sampling system consists of the standard EPA train with the adsorbent sampler (Figure 2-3) located between the filter and the impingers. With this system filterable particulate can be determined from the filter catch and the probe wash according to Method 5, whereas the organic materials present can be determined from the analysis of the filterable particulate and the adsorbent sampler catch. The impingers are only used to cool the stream and protect the dry-gas meter, and their contents are discarded.

2.1.4 Opacity Measurement

Stack opacity was measured with a Dynatron Model 1100 Opacity Monitoring System. The Model 1100 opacity monitor is a double pass transmissometer which measures the light transmittance through a flue gas. The transceiver unit contains the light source, the detector, and electronic circuitry. A reflector is mounted in the end of a slotted probe which is attached to the transceiver and is inserted into a stack or duct through a conventional stack sampling port. The probe causes negligible flow disturbance, and an air purge keeps the optical window and reflector clean. The transceiver output is transmitted to a portable control unit which displays either opacity or optical density automatically correlated from differences between the path length of the transmissometer and the mean diameter of the stack out.

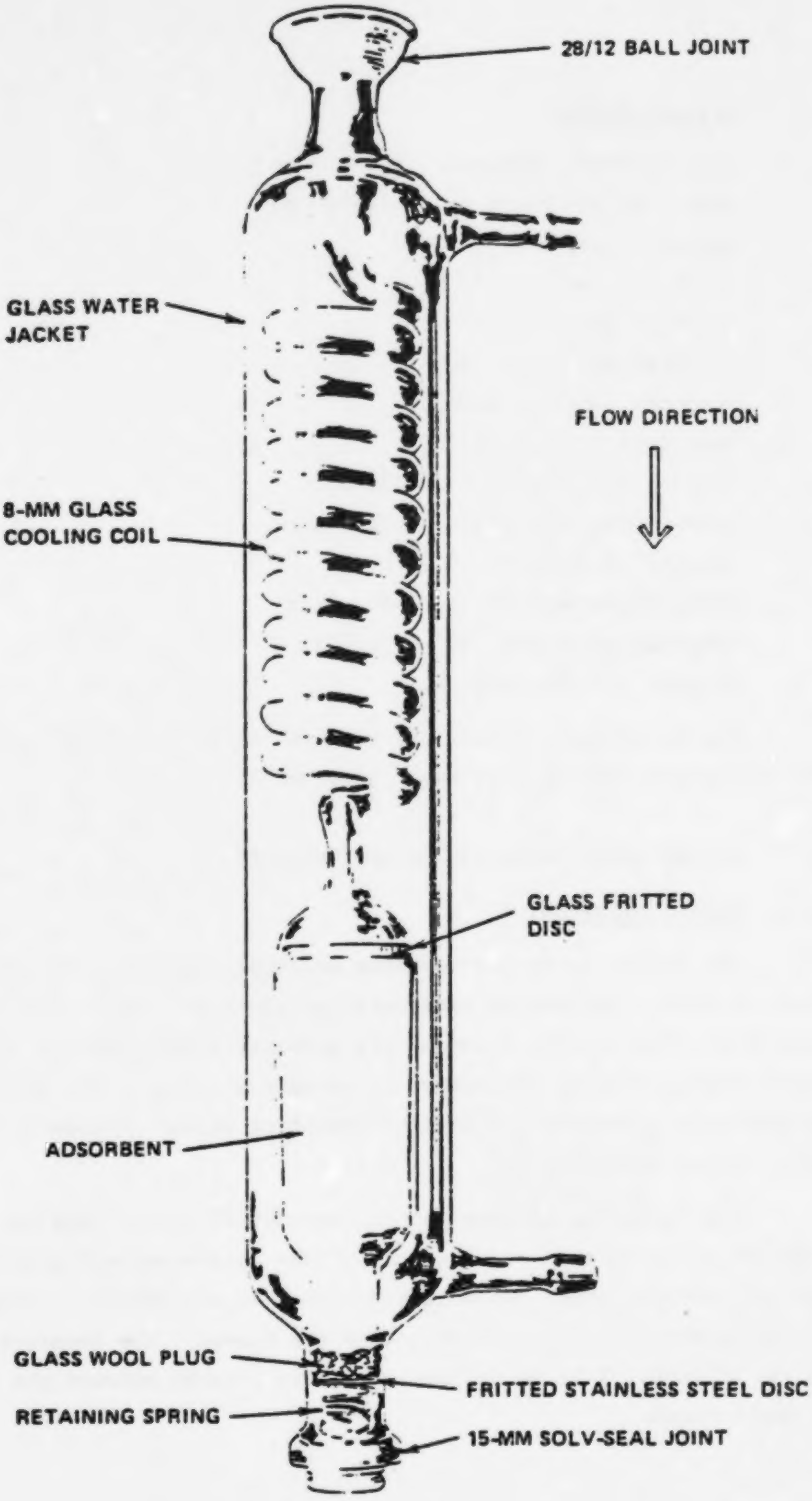


Figure 2-3. Mark III adsorbent sampling system.

Specifications

Peak spectral response: 500-600 nm
Mean spectral response: 500-600 nm
Relative response: < 10%
Angle of view: < 4°
Angle of projection: < 2°
Calibration error: < 2%
Response time: 1 second
Zero drift: < 1% (24 hrs)
Calibration drift: < 1% (24 hrs)
Operational test period: 168 hours
Output: 0-1 VDC
Power requirements: 115 VAC/60 Hz
Temperature range: 40° F to 125° F
Weight: 27 lbs (approx.)

The transceiver lenses are cleaned daily, and an air purge is used to keep the lenses free of dirt while inserted in the stack.

2.2 BOILER DESCRIPTION AND CHARACTERISTICS

2.2.1 Boiler Description

The boiler is of the two-drum Stirling type built by Babcock and Wilcox in 1960. The boiler nameplate rating is 20.2 kg/s (160,000 lb/hr) steam flow. The unit is fired by six spreader stoker feeders supplied by the Detroit Stoker Company (described in paragraph 2.2.2). The stoker is equipped with a front-end discharge traveling grate. Figure 2-4 shows the boiler layout and elevation.

The boiler is balanced draft; combustion air is supplied from underneath the grate by a forced-draft fan. The undergrate air plenum is divided into two sections which are adjustable with an air damper. Grate combustion air can be biased left to right across the stoker. The negative draft of the furnace is supplied by an induced-draft fan located between the air preheater and smoke stack.

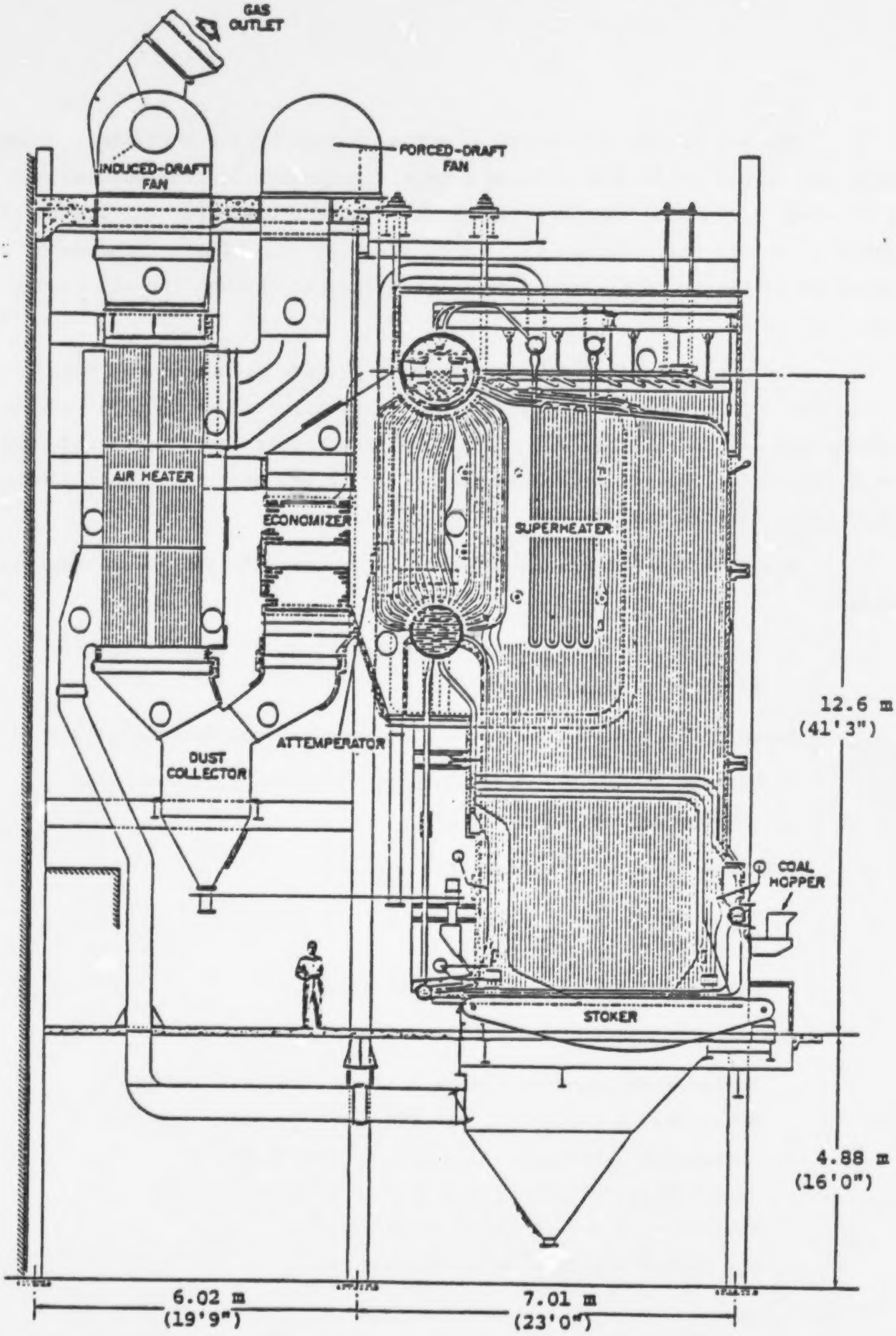


Figure 2-4. Site 4 boiler

The boiler has an economizer and a pendant-type superheater. Combustion air is preheated by a tubular-type air preheater located between the induced-draft fan and the dust collector. The air preheater was previously found to be defective during testing by KVB (Ref. 1). The defect caused a fraction of the incoming air to be short circuited through the air heater and out the stack.

Fly ash is removed with a Western Precipitator Multiclone dust collector. This mechanical type cyclone dust collector is located between the economizer and the air heater. The steam produced is superheated and used both for electrical power generation and for direct heating. The following data apply to this unit:

Based on 27.9 MJ/kg (12,000 Btu/lb) southern Illinois coal (April, 1961):

- Maximum continuous steam output, 20.2 kg/s (160,000 lb/hr)
- Efficiency (thermal), 87.78%

Based on 19.2 MJ/kg (8,240 Btu/lb) Montana coal December, 1972):

- Maximum continuous steam output, 16.4 kg/s (130,000 lb/hr)
- Efficiency (thermal), 82.63%

Steam conditions at superheater outlet:

- T_{out} = 672K (750° F)
- P = 2.9 MPa (425 psig)
- Design pressure = 6.8 MPa (1000 psig)

Heating surfaces:

- Boiler heat transfer area = $1.316 \times 10^3 m^2$ (14,168 $ft.^2$)
- Water wall = $2.0 \times 10^2 m^2$ (2,158 $ft.^2$)
- Superheater, primary = $3.5 \times 10^2 m^2$ (3,778 $ft.^2$)
- Superheater, secondary = $1.61 \times 10^2 m^2$ (1,731 $ft.^2$)
- Economizer = $3.95 \times 10^2 m^2$ (4,250 $ft.^2$)
- Air heater = $1.21 \times 10^3 m^2$ (13,030 $ft.^2$)

2.2.2 Stoker Description

The Site 4 boiler is fired by a Detroit Stoker Company Rotograte spreader stoker. Figure 2-4 includes a side view of the stoker. This stoker is fired by six individual feeders. Raw coal leaves the bunker and is weighed by two coal scales as the coal is divided into left and right feed streams. After the coal scales, the coal enters the left and right coal distributors. Each distributor supplies raw coal to three feeders.

Each feeder can be independently adjusted to distribute coal on the grate. Three mechanisms give this control. The first is a spill plate adjustment which regulates the point at which coal is dropped onto the rotating paddle wheel. Second, the length of stroke of the feed plate which pushes the coal over the spill plate may be adjusted. The last mechanism is the rotor speed. Additionally, the fuel bed thickness may be controlled by the speed of the traveling grate.

2.2.3 Daily Test Activity

This section describes the daily test activity at Site 4 following the monitor certification tests. The schedule of monitor certification test events is presented in paragraph 3.1. A schedule of daily events is presented in Table 2-2.

The data from the gaseous analyzers (NO, CO, CO_2, and O_2) were continuously recorded on strip chart recorders. Boiler control room data (steam flow, pressure, etc.) were recorded eight times daily by the KVB technician. Plant operating personnel recorded the data on an hourly basis. The gaseous emissions data were recorded only during an eight-hour shift, but the strip chart recorders recorded the data 24 hours per day, 7 days per week, along with an automatic data-logger. No control room data were recorded during the week-ends; however, the technician calibrated the instruments during the week-ends.

Daily tasks consisted of (1) calibration and recording data, (2) consultation with operators to assure operation in the low-NO_x mode, (3) periodic maintenance of instruments and sample system, (4) visual inspection and troubleshooting of the sampling system and instrumentation console, and (5) procuring supplies and equipment for the particulate and Method 7 tests.

TABLE 2-2. SCHEDULE OF DAILY EVENTS - SITE 4

Time	Event
0800	Calibrate (zero and span) gaseous analyzers (NO, CO_2, CO, and O_2). Record gaseous emissions data. Record boiler control room data. Consult with operators concerning boiler operation.
0845	Calibrate opacity monitor.
0900	Perform daily systems checkout.
1000	Calibrate and record gaseous emissions data.
1200	Calibrate and record gaseous emissions data. Record control room data.
1400	Calibrate and record gaseous emissions data.
1600	Calibrate and record gaseous emissions data. Record control room data.
1700	Calibrate analyzers prior to departing plant. Perform visual check of sampling systems and boiler operation. Leave instructions with operators.

SECTION 3.0

TEST RESULTS

This section summarizes the emission and efficiency data collected on the coal-fired spreader stoker boiler. The boiler was tested in the as-found condition initially and for 30 days in the low-NO_x condition. The tests were conducted with western coal as the fuel. The results presented herein summarize the gaseous and particulate emissions data, efficiency, and conclusions for the boiler operating under low NO_x conditions for extended duration.

3.1 CONTINUOUS MONITOR CERTIFICATION TESTS

The continuous monitor described in the previous section was used to measure the boiler gaseous emissions. Following shipment to the test site, the monitoring system was installed and certification tests performed in accordance with Performance Specifications 2 (PS2) and 3 (PS3), 40 CFR 60. Appendix B (Appendix D in this document) establishes minimum performance specifications that the NO monitoring system must meet in terms of eight parameters: accuracy, calibration error, two- and 24-hour zero drifts, two- and 24-hour calibration drifts, response time, and operational period.

The continuous monitor system was installed and instruments were initially calibrated on August 8, 1979. The following day the monitor performance certification began. A daily event schedule for the certification tests is presented in Table 3-1.

The performance of the continuous monitor is summarized in Table 3-2. Also shown in the table are the monitor specifications extracted from PS2 and PS3. Tables C-1 through C-18, Appendix C, show the performance of each of the analyzers for the certification tests.

TABLE 3-1. SCHEDULE OF CERTIFICATION TEST EVENTS SITE 4, COAL-FIRED SPREADER STOKER

Date	Time	Event
8/8/79	1500	Calibration error determination
8/9/79	0900	Initial 24-hour zero and span reading Initial 2-hour zero and span reading
8/9/79	1100	1st 2-hour zero and span drift point
8/9/79	1300	2nd 2-hour zero and span drift point
8/9/79	1500	3rd 2-hour zero and span drift point
8/9/79	1700	4th 2-hour zero and span drift point
8/9/79	1900	5th 2-hour zero and span drift point
8/9/79	2100	6th 2-hour zero and span drift point
8/9/79	2300	7th 2-hour zero and span drift point
8/10/79	0900	1st 24-hour zero and calibration drift point. Initial 2-hour zero and calibration reading.
8/10/79	1100	8th 2-hour zero and span drift point
8/10/79	1300	9th 2-hour zero and span drift point
8/10/79	1500	10th 2-hour zero and span drift point
8/10/79	1700	11th 2-hour zero and span drift point
8/10/79	1900	12th 2-hour zero and span drift point
8/10/79	2100	13th 2-hour zero and span drift point
8/10/79	2300	14th 2-hour zero and span drift point
8/11/79	0900	15th 2-hour zero and span drift point
8/11/79	1100	16th 2-hour zero and span drift point
8/11/79	0900	2nd 24-hour zero and calibration drift point
8/12/79	0900	3rd 24-hour zero and calibration drift point
8/8/79	1100	Instrument response time tests
8/13/79	0900	4th 24-hour zero and calibration drift point
8/11/79	1130	1st set of relative accuracy samples taken
8/11/79	1230	2nd set of relative accuracy samples taken
8/11/79	1330	3rd set of relative accuracy samples taken
8/11/79	1430	4th set of relative accuracy samples taken
8/11/79	1530	5th set of relative accuracy samples taken
8/11/79	1630	6th set of relative accuracy samples taken
8/11/79	1730	7th set of relative accuracy samples taken
8/11/79	1830	8th set of relative accuracy samples taken
8/11/79	1930	9th set of relative accuracy samples taken
8/14/79	0900	5th 24-hour zero and calibration drift point
8/15/79	0900	6th 24-hour zero and calibration drift point
8/16/79	0900	7th and final 24-hour zero and calibration drift point

TABLE 3-2. INSTRUMENT SPECIFICATIONS AND PERFORMANCE

Parameter	Specifications*	Performance
A. Thermo Electron Series 10 NOx Analyzer		
1. Accuracy	≤ 20% of mean ref. value	7.77%, 9.17%
2. Calibration error mid	≤ 5% cal gas value	1.13%
high	≤ 5% of cal gas value	0.55%
3. Zero drift (2-hour)	2% of span	0.20%
4. Zero drift (24-hour)	2% of span	0.19%
5. Calibration drift (2-hour)	2% of span	0.35%
6. Calibration drift (24-hour)	2.5% of span	0.52%
7. Response time	15-minute maximum	82 sec
8. Operational period	168-hour minimum	727 hr
B. Horiba Instruments PIR 2000 CO_2 Analyzer		
1. Zero drift (2-hour)	≤ 0.4 pct CO_2	.063%
2. Zero drift (24-hour)	≤ 0.5 pct CO_2	.09%
3. Calibration drift (2-hour)	≤ 0.4 pct CO_2	.155%
4. Calibration drift (24-hour)	≤ 0.5 pct CO_2	.257%
5. Response time	10 minutes	97 sec
6. Operational period	168-hour minimum	727 hr
C. Beckman Instruments Model 742 O_2 Analyzer		
1. Zero drift (2-hour)**	≤ 0.4 pct O_2	DNA*
2. Zero drift (24-hour)**	≤ 0.5 pct O_2	DNA*
3. Calibration drift (2-hour)	≤ 0.4 pct O_2	0.11%
4. Calibration drift (24-hour)	≤ 0.5 pct O_2	.595%
5. Response time	10 minutes	73 sec
6. Operational period	168-hour minimum	727 hr

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* Instrument has no zero adjustment.

The data presented in Table 3-2 show that analyzers in the continuous monitor bettered the performance specification values for each parameter for each instrument.

Certified calibration gases were obtained from Scott Environmental Technology Inc. The calibration gases included 50% and 90% span gases for the NO, CO_2, CO, AND O_2 analyzers, and a zero gas. In addition to the certified analysis supplied by the vendor, sample flasks were taken for each calibration gas and sent to an independent laboratory for analysis.

Relative accuracy tests for the NO analyzer were performed as outlined in PS2 using EPA Reference Method 7 (phenoldisulfonic acid [PDS] colorimetric) as the standard. Nine sets of three PDS flasks were collected at one-hour intervals at the beginning and end of the 30-day test period. All sample flasks were returned to an independent laboratory for analysis. The results of the relative accuracy determination are shown on pages C-14 and C-15 for the start and end of the 30-day tests. Both tests showed that the NO instrument greatly exceeded the accuracy requirements of PS2. The relative accuracy of the Thermo Electron NO analyzer was about 8% based on the first test series and about 9% based on the final test series. The relative accuracy requirement published in PS2 is $\leq$ 20% of mean reference value.

3.2 COAL-FIRED STOKER BOILER TESTS

The continuous monitor system was installed by KVB personnel on August 7, 1979 in the control room at Site 4, a coal-fired spreader stoker boiler. A single unheated 9.5mm (3/8") nylon sample line was strung from the duct downstream of the induced draft fan to the continuous monitor. A single stainless steel probe with a sintered stainless steel filter was installed in one of the center sampling ports of the duct. Particulate samples were taken from the side of the duct according to EPA Method 5.

The boiler was initially tested in the baseline or as-found condition on August 11. The boiler load for these two tests was approximately 27.7 MW and 28.1 MW (94500 and 96000 lb steam/hr). Triplicate PDS flask samples were collected at hourly intervals for the monitor relative accuracy determination. The average NO emission level was 279 ng/J (474 ppm @ 3% O_2, dry) for the nine-hour test.

Two days later the boiler was adjusted to the low NO_x operating condition. The NO_x control technology used at this facility was low excess air (staged combustion showed no effect). The excess air in this stoker is limited by smoke, ash clinkering, and burnout.

Clinkers are a fused mass of slag globules. The formation of clinkers involves ash fusion, flow, and solidification. The viscosity of coal ash slag is important in clinker formation. If the slag globules have low viscosity at the temperture to which they are exposed, they will flow downward toward the grate where they encounter entering air and are cooled. If this causes them to stop flowing, they will solidify in fragments and will not coalesce to form a larger clinker.

When coal burns on a grate, trouble with clinkers can be avoided by burning a thin fuel bed. When there are no clinkers, the flow of air through the fuel bed is uniform over the entire grate, and the desired rate of combustion is maintained. Once clinkers have started, they form at an increasing rate because the restriction to air flow by the clinker slows the combustion and causes the fuel to accumulate into a thicker fuel bed. Restricted air flow and thick fuel beds cause reducing conditions which favor clinker formation. This causes unburned fuel to drop into the ash pit.

Excess oxygen was lowered to approximately 9%, which is a level operating personnel felt was the lowest practical limit based on the above criteria. The operating personnel were quite apprehensive about lowering the excess O_2 by any amount. The excess O_2 could have easily been maintained at least a half a percent lower. This apprehension is apparent when looking at the hourly data (found in Appendix F). These data show that the operators kept the O_2 lower when our personnel were in the plant, and used their standard O_2 levels at other times (all shifts of operators were informed which excess O_2 level to use).

Triplicate Method 5 particulate tests were conducted after the boiler operating conditions were stabilized in the low NOx condition. Triplicate Method 5 measurements were again made at the end of the test period with the boiler still in the low NOx condition. One of these three tests included collecting a sample for POM analysis as described in Section 2.1.3. Particulate tests including POM were then conducted in the baseline condition.

Coal, bottom ash, and fly ash samples were collected as shown in Table 3-6. A summary of all emissions data is presented in Table 3-3.

3.2.1 Gaseous Emissions

During a previous program (Ref. 1), the effect of excess oxygen on NO emissions was evaluated for this boiler. As seen by Figures E-4 and E-5 in Appendix E, NO emissions were higher for eastern coal than for western coal by approximately 100 ppm in the O_2 range examined in these particulate tests.

In the same fashion as most boilers, this unit exibited a sharp decrease in NO emissions with decreasing O_2. Figure 3-1 shows a decrease of approximately 300 ppm NO per percent O_2. This figure represents data from the particulate tests only as an average case. Figure 3-1 also shows that the baseline condition produces points with higher NO emissions than in the low excess air condition. From the particulate tests alone a reduction of 19% from baseline was achieved for NO emissions in the low excess air mode.

Additionally, this unit shows a sharp decrease in NO emissions with decreasing steam load as seen in Figure 3-2 and the data presented in Appendix E. These data represent short duration tests however any may not be statistically significant.

An interesting trend was also found in Figure 3-3. Because of entrainment of fine coal particles a reduction of undergrate air also reduces particulate loading along with NO emissions. This is a bonus that could be found in many older coal-fired units.

An examination of Figure 3-4 will show the statistical spread of NO emissions for the test period. The geometric mean is 211 ng/J (360 ppm) with a geometric dispersion of 1.06. This figure also shows that 99% of the time the NO emissions will be less than 245 ng/J.

TABLE 3-3. SUMMARY OF OBSERVATIONS AND GASEOUS AND PARTICULATE EMISSIONS AT SITE 4 (COAL-FIRED SPREADER STOKER)

	24 HOUR DATA						PARTICULATE DATA										
	Load		O_2	CO_2	NO		Load		O_2	CO_2	Particulates		Opacity	Efficiency	Stack T		
Date	MW	10^3 lb./hr.	%	%	ppm 3%* O_2, dry	ng/J	MW	10^3 lb./hr.	%	%	ng/J	lb./MMBTU	%	%	K	°F	Comments
8/11/79	24.6	84	9.3	10.1	390	229	27.7	94.5	8.9	10.4	667	1.55	35	84.47	430	315	Baseline - High load
							28.1	96.0	9.5	10.4	612	1.42	35	84.58	430	315	Baseline
8/12/79	19.1	65	10.8	8.6	389	229											High EA
8/13/79	21.7	74	10.0	9.6	371	218	27.4	93.5	8.5	11.3	450	1.05	25	85.45	432	317.5	LEA
8/14/79	21.4	73	10.2	9.5	341	200	27.5	94.0	8.45	11.2	543	1.26	25	85.78	426	307.5	LEA
8/15/79	21.2	72	10.5	9.2	384	225											LEA
8/16/79	21.7	74	9.9	9.6	360	211											LEA
8/17/79	23.0	78	9.5	9.7	362	212											LEA
8/18/79	22.0	75	9.9	9.4	369	217											LEA
8/19/79	18.3	62	10.8	8.3	393	231											High O_2
8/20/79	24.5	84	9.4	9.8	374	219											LEA
8/21/79	24.0	82	9.2	10.0	338	198											LEA
8/22/79	23.5	80	9.5	9.8	368	216											LEA
8/23/79	21.7	74	10.4	8.9	350	206											LEA
8/24/79	21.5	73	9.9	9.8	358	210											LEA
8/25/79	19.5	67	10.5	9.1	356	209											LEA
8/26/79	18.4	63	10.6	8.7	340	199											LEA
8/27/79	22.9	78	9.9	9.6	374	220											LEA
8/28/79	24.1	82	9.3	9.9	348	204											LEA
8/29/79	25.9	88	9.1	10.4	372	218											LEA
8/30/79	24.8	85	9.4	10.1	368	216											LEA
8/31/79	26.8	91	8.7	10.7	350	206											LEA
9/01/79	22.7	77	9.7	9.9	348	204											LEA
9/02/79	18.5	63	10.5	9.1	335	208											LEA
9/03/79	19.1	65	10.3	9.5	333	196											LEA
9/04/79	27.2	93	8.8	10.8	353	207											LEA
9/05/79	25.7	88	9.1	10.4	363	213											LEA
9/06/79	23.4	80	9.7	9.9	355	208	27.8	95	8.82	10.95	424	0.99	25	84.81	439	330	LEA
9/07/79	22.2	76	9.7	9.7	358	210	28.0	95.5	8.7	10.95	451	1.05	25	85.19	435	323	LEA
9/08/79	19.8	68	10.1	9.1	385	226	25.8	88	8.82	10.74	500	1.16	25	85.48	430	314	LEA
9/09/79	19.1	65	10.2	9.1	407	239											High O_2
9/10/79	23.8	81	9.4	10.1	374	220	27.5	94	8.5	11.04	575	1.34	30	84.68	436	326	LEA, POM
9/11/79	22.8	78	8.8	10.4	382	224	27.8	95	8.96	10.31	600	1.40	25	85.33	430	314	Baseline, POM
9/12/79	-	-	10.3	8.5	349	211											TERMINATED MONITORING

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*Corrected to 3% O_2, dry

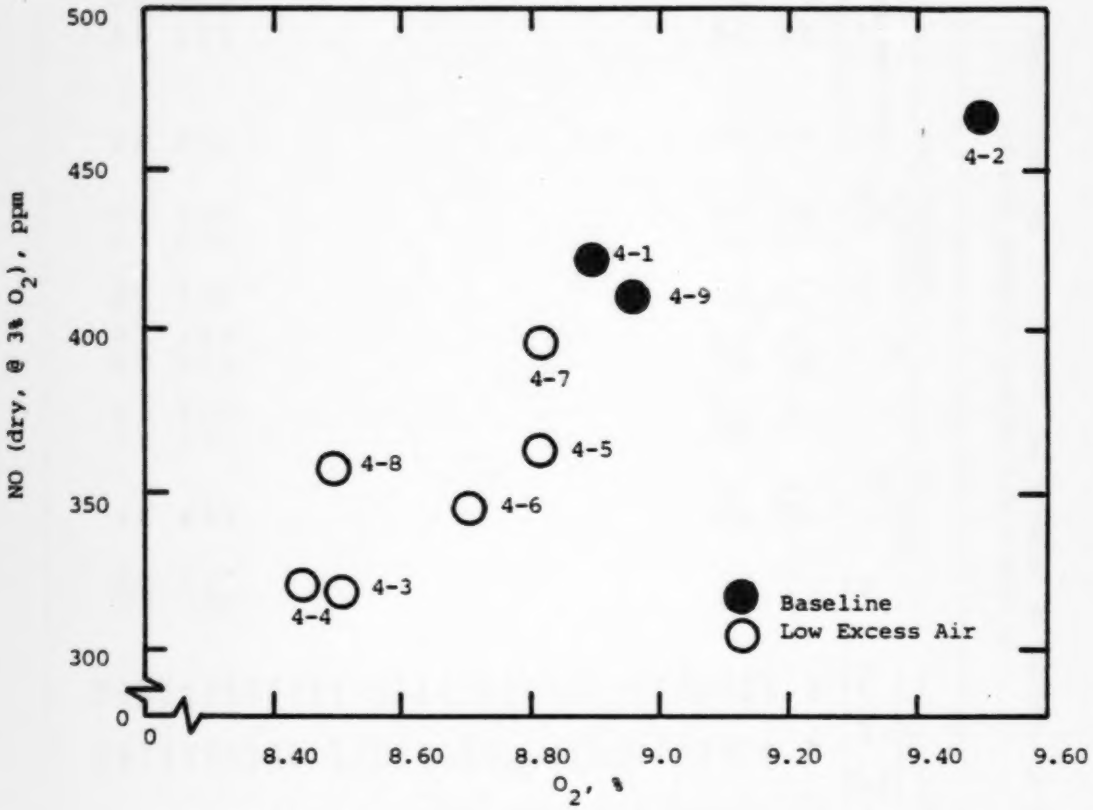


Figure 3-1. NO Emissions as a Function of Excess O_2.
Site 4 - Coal-Fired Spreader Stoker.

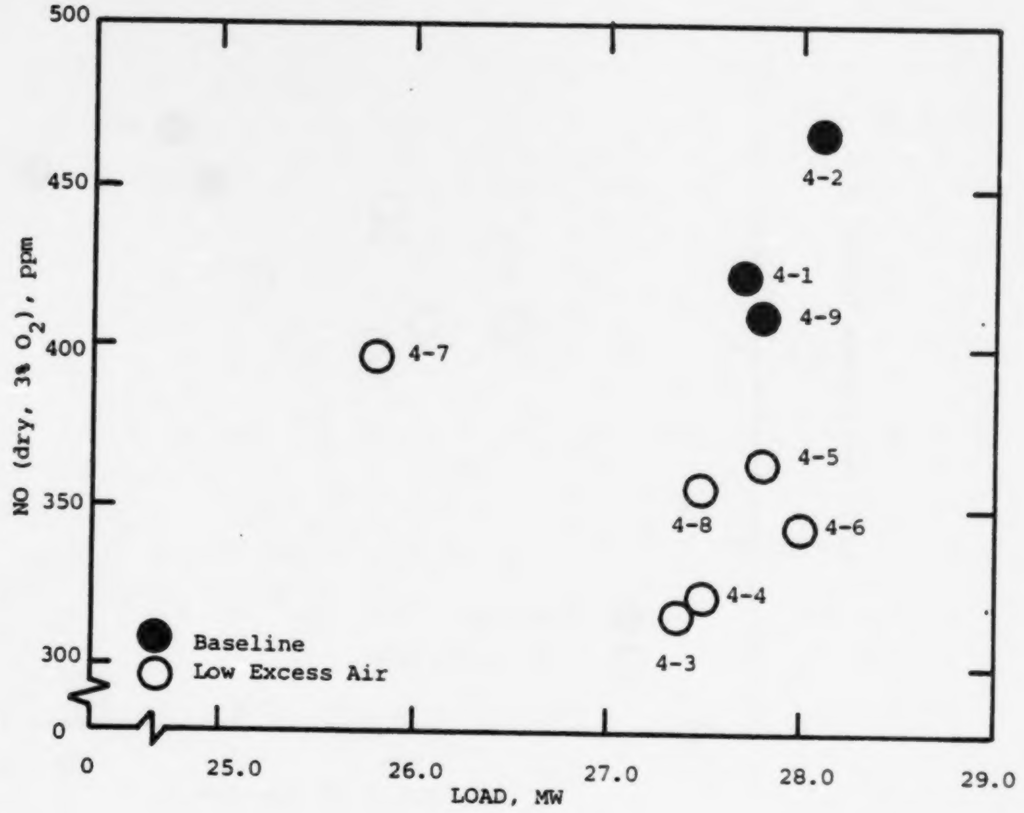


Figure 3-2. NO Emissions as a Function of Boiler Load Site 4 - Coal-Fired Spreader Stoker.

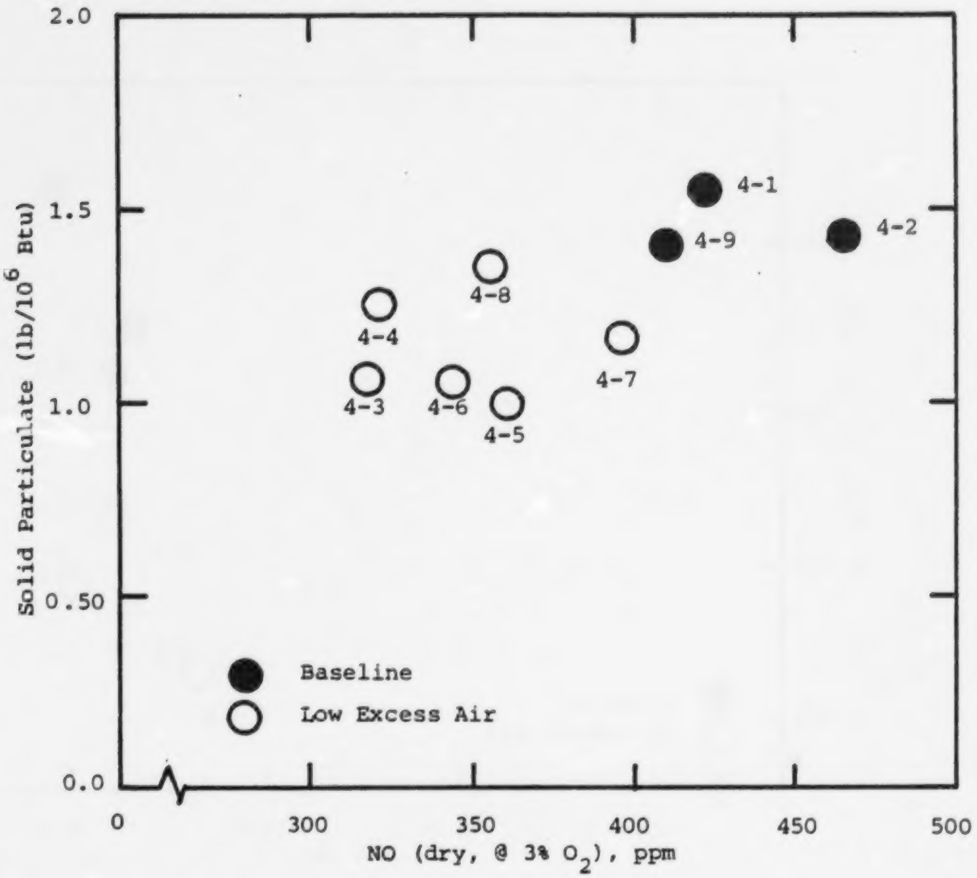


Figure 3-3. Solid Particulate Loading as a Function of NO Emissions. Site 4, Coal-Fired Spreader Stoker.

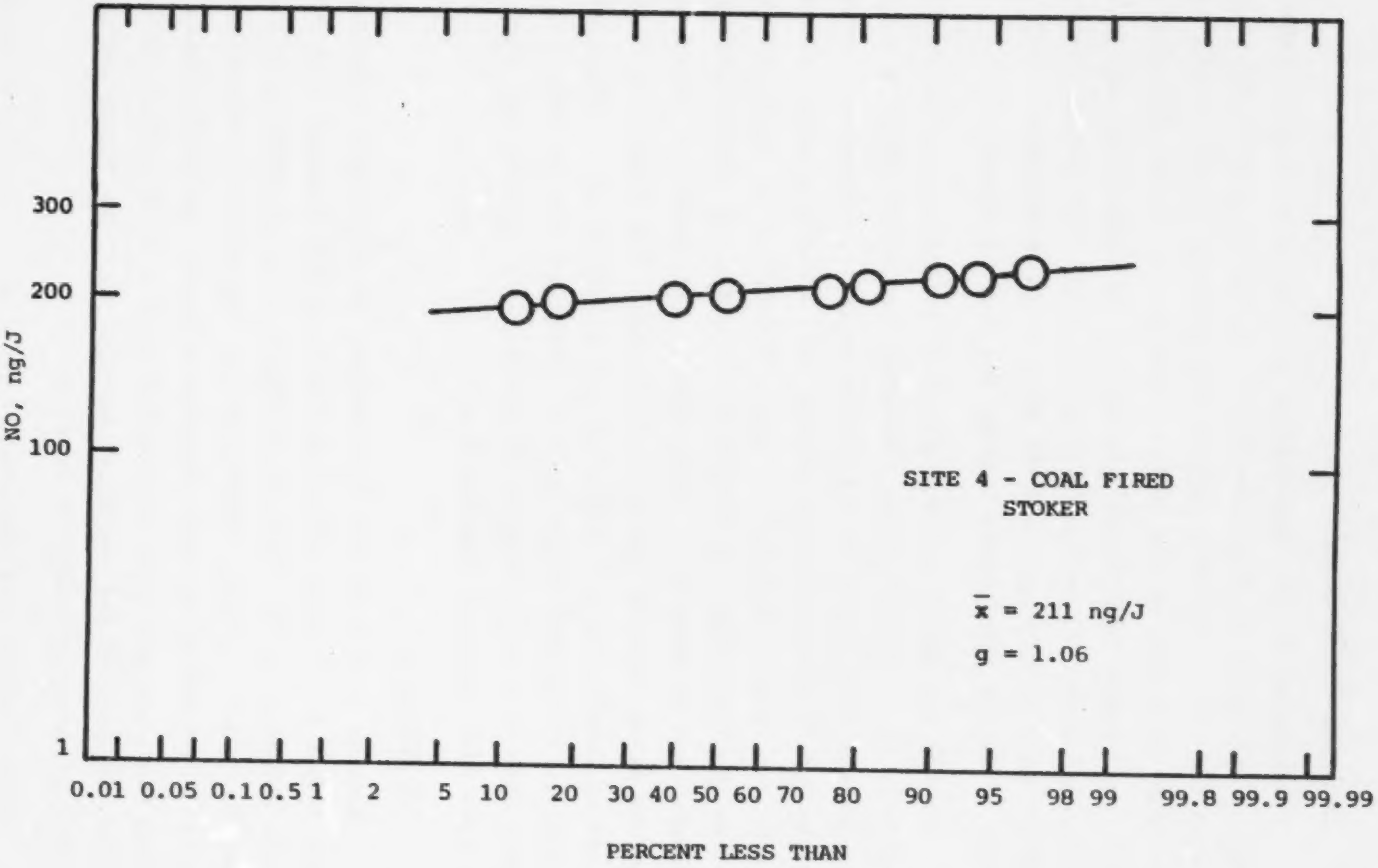


Figure 3-4. NO Emissions Site 4 Coal-Fired Spreader-Stoker.

3.2.2 Particulate Emissions

The results of the particulate tests are presented in Table 3-4 for low excess air tests and baseline tests. Two of the tests (NO.'s 4-8 & 4-9) were also used for collecting samples for analysis of polycyclic organic matter (POM) by modifying the Method 5 sampling train as described in Section 2.1.3. The average particulate loading for the unmodified operation was found to be 626 ng/J (1.46 lb/10^6 Btu) while the average particulate loading in the LEA mode of operation was 491 ng/J (1.14 lb/10^6 Btu). This is a decrease of 22% in particulate loading for low NOx operation.

Figure 3-5 shows that the amount of particulates (Figure 3-3) decreases as excess O_2 is decreased. This indicates that entrainment is a major factor in particulate loading for this specific boiler. Although not many different boiler load settings were used, Figure 3-6 shows that particulate loading does not seem to be a function of load. Figure 3-3 is unique in that it indicates the low excess air condition reduced solid particulates in addition to reducing the NO emissions. This clearly indicates that entrainment was indeed the major cause of particulate loading. The reason for this entrainment was of course too many fines for the given air flow. The operators at this test site were previously using a harder eastern coal with less fines. However, they were still running their boiler on western coal with the same techniques they used with eastern coal.

3.2.3 POM Emissions

Samples were collected for analysis of polycyclic organic matter using a Method 5 sampling train with XAD-2, a POM absorber, inserted. Sample time was extended to two hours to provide a large enough sample for Battelle to analyze. Following the sampling period, the organic resin module was sealed and returned to Battelle Columbus Laboratories for analysis. The sampling probe and glassware were washed with a 50-50 mixture of methylene chloride and methanol per Battelle instructions. The filter and wash were also sent to Battelle following weighing.

These samples were analyzed by capillary-EI GC-MS utilizing a 30M SE-52 column with hydrogen as a carrier gas. All data were collected by single ion monitoring (SIM) to improve selectivity and sensitivity.

TABLE 3-4. PARTICULATE DATA SUMMARY SITE 4, COAL-FIRED SPREADER-STOKER

Test No.	Date 1979	Load		O2 %	Particulates		Opacity %	Test Description
		MW	10^3lb/hr		ng/J	lb/MMBtu		
4-1	8-11	27.7	94.5	8.9	667	1.55	35	Baseline
4-2	8-11	28.1	96	9.5	612	1.42	35	Baseline
4-3	8-13	27.4	93.5	8.5	450	1.05	25	LEA
4-4	8-14	27.5	94	8.45	543	1.26	25	LEA
4-5	9-6	27.8	95	8.82	424	0.99	25	LEA
4-6	9-7	28.0	95.5	8.71	451	1.05	25	LEA
4-7	9-8	25.8	88	8.82	500	1.16	25	LEA
4-8	9-10	27.5	94	8.5	575	1.34	30	LEA, POM
4-9	9-11	27.8	95	8.96	600	1.40	25	Baseline, POM

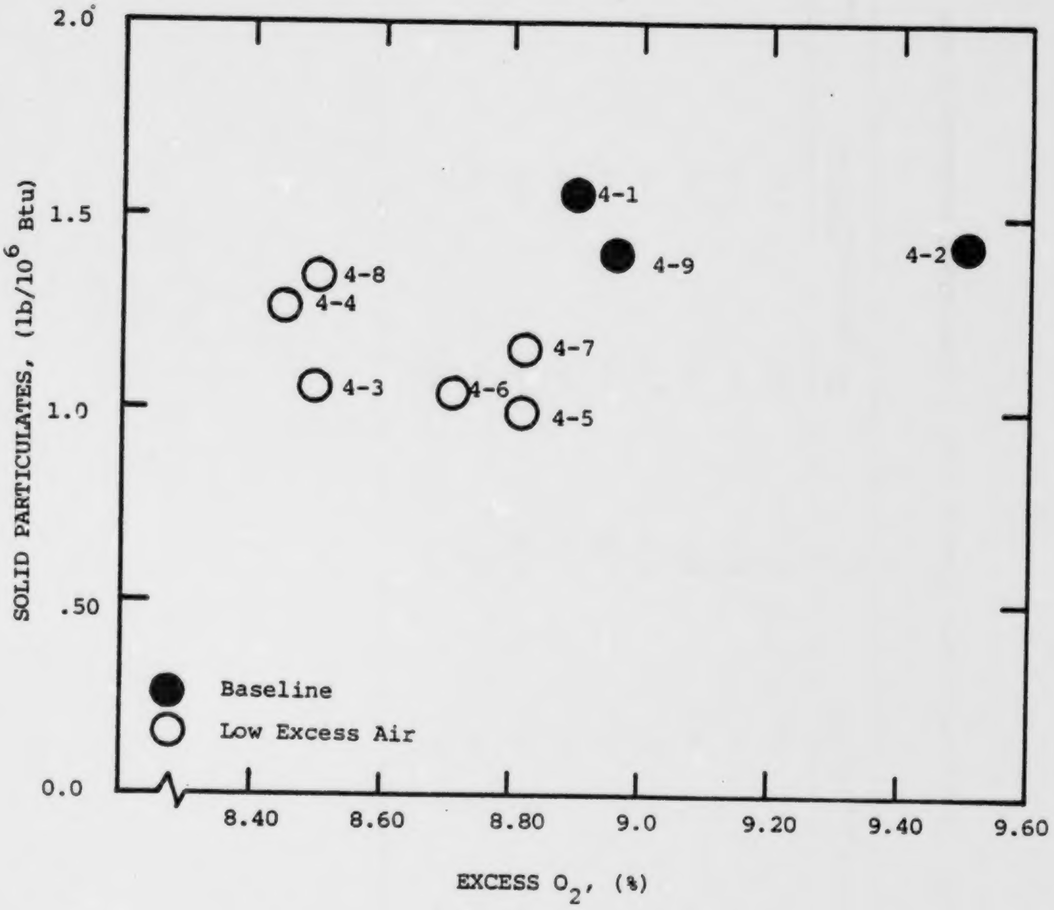


Figure 3-5. Solid Particulate Loading as a Function of Excess O_2. Site 4 Coal-Fired Spreader Stoker.

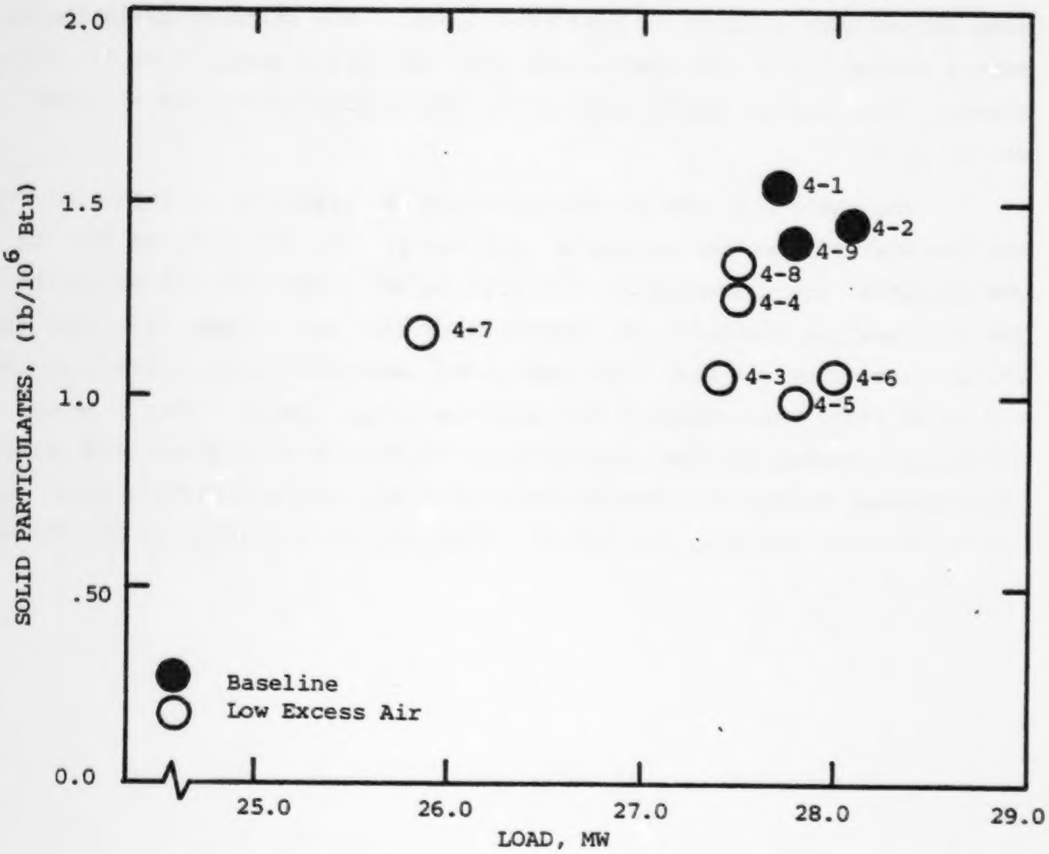


Figure 3-6. Solid Particulate Loading as a Function of Boiler Load Site 4 Coal-Fired Spreader Stoker.

The results of the analyses are presented in μg per total sample. The quantitative detection limit was 0.5 μg; thus samples with POM's present at levels lower than this are reported as <0.5 μg (the standard deviation at lower levels was prohibitively high for accurate quantitation). Samples reporting POM values of ND (none detected) are at a level of less than 0.1 μg (the approximate qualitative detection limit). The standard deviation on points around 0.5 μg averaged around ±20%, at levels around 5 μg it averaged around ± 15%, and at levels above 12 μg the standard deviation averaged around ± 10%.

The results of the Battelle analyses are presented in Table 3-5 for the low NOx and baseline operating conditions. The POM analyses for the low NOx condition are presented in the first column under test 4-8 while the data for the baseline condition are presented in the last column. For each test the extracts from all four test components (adsorbent trap, filter, cyclone, and probe wash) were combined for analysis as one sample. Only a small difference between the two conditions is evident in only three sets of species: phenanthrene, methyl anthracenes/phenanthrenes, and dibenzanthracenes. It is therefore concluded that the low NO_x condition has not affected POM emissions.

TABLE 3-5. SUMMARY OF POM ANALYSES SITE 4, COAL-FIRED SPREADER STOKER

POM	Test 4-8 LEA		Test 4-9 Baseline	
	μg	μg/m^3	μg	μg/m^3
Phenanthrene	1.5	0.739	2.0	0.855
Anthracene	ND	ND	ND	ND
Methyl Anthracenes/Phenanthrenes	0.6	0.296	0.9	0.385
Fluoranthene	<0.5	<0.246	<0.5	<0.214
Pyrene	<0.5	<0.246	<0.5	<0.214
Methyl Pyrene/Fluoranthene	ND	ND	ND	ND
Benzo(c)phenanthrene	ND	ND	ND	ND
Benz(a)anthracene	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND
Methyl Chrysenes	ND	ND	ND	ND
Dimethylbenzanthracenes	ND	ND	ND	ND
Benzofluoranthenes	ND	ND	ND	ND
Benz(e)pyrene	ND	ND	ND	ND
Benz(a)pyrene	ND	ND	ND	ND
Perylene	ND	ND	ND	ND
Indeno-pyrene	<0.5	<0.246	<0.5	<0.214
Benzo(ghi)perylene	<0.5	<0.246	<0.5	<0.214
Methylcholanthrenes	<0.5	<0.246	0.5	<0.214
Dibenzanthracenes	<0.5	<0.246	ND	ND
Dibenzpyrenes	ND	ND	ND	ND
Coronene	<0.5	<0.246	<0.5	<0.214
Total Sample Volume standard m^3	2.029 m^3		2.340 m^3	
Load	27.5 MW		27.8 MW	
Excess O_2, %	8.5		9.0	
Particulates	575 ng/J		600 ng/J	

3.2.4 Boiler Efficiency

Boiler efficiency calculations were made for as-found and low NOx operating conditions. The ASME Abbreviated Efficiency Test method was used to determine the boiler efficiency. This test method is described in Appendix A.

Coal, fly ash, and bottom ash samples were collected during each set of particulate tests. Coal samples were submitted to an independent laboratory for ultimate and heating value analyses. Fly and bottom ash samples were analyzed for carbon content and heating value. The results of these analyses are tabulated in Table 3-6. These data indicate that the carbon and moisture content vary the most within these coals.

Combustible losses were calculated using the ash content of the fuel, the particulate loading, and the ash heating value. The fly ash was determined from the flue gas particulate loading, an assumed multiclone collection efficiency of 70% and fuel flow rate. The total ash was determined from the fuel analysis and the fuel flow rate. Bottom ash was the difference between total ash and fly ash. A mass weighted heating value of dry refuse was then calculated and used for determining the combustible losses. Table 3-7 lists a summary of the boiler efficiencies. It is apparent from the data presented in this table that LEA operation results in an efficiency increase of about 1.2% with a primary contribution due to dry gas losses. Another contribution was improper burnout of the fuel bed. It was observed that some hot coals dropped into the ash pit. Thus, while the ash had no heating value (as seen in Table 3-6) when it was analyzed some additional heat was lost through the ash pit. Some of this heat is of course transferred back up through the boiler

Figure 3-7 shows unit efficiency as a function of excess oxygen for the boiler. This figure clearly illustrates the effect that LEA firing has on boiler efficiency. This curve shows that efficiency increases approximately 1% for each 1.5% decrease in excess oxygen.

TABLE 3-6. SUMMARY OF COAL AND ASH ANALYSES FOR SITE 4
(Coal-Fired Spreader Stoker)

Test Date	4-1 8/11/79	4-2 8/11/79	4-3 8/13/79	4-4 8/14/79	4-5 9/6/79	4-6 9/7/79	4-7 9/8/79	4-8 9/10/79	4-9 9/11/79
Ultimate Analysis:									
Coal									
(in percent by weight)									
Moisture	24.83	24.83	23.38	22.77	22.28	22.54	22.54	22.88	21.10
Carbon	46.69	46.69	48.28	49.39	48.75	49.17	49.17	48.36	49.95
Hydrogen	3.35	3.35	3.56	3.53	3.47	3.64	3.64	3.46	3.55
Nitrogen	0.76	0.76	0.79	0.80	0.77	0.80	0.80	0.79	0.80
Sulfur	0.82	0.82	0.57	0.50	0.64	0.74	0.74	1.07	0.65
Ash	10.24	10.24	8.91	8.35	9.21	9.34	9.34	9.54	9.44
Oxygen (by difference)	13.31	13.31	14.51	14.66	14.88	13.77	13.77	13.90	14.51
Heat of Combustion:									
Gross Btu/lb.	8270	8270	8840	8888	8740	8925	8925	8529	8984
Net Btu/lb.	7960	7960	8510	8561	8410	8588	8588	8208	8655
Ash									
Fly Ash:									
Carbon %	5.30	5.30	5.30	5.30	11.59	11.59	11.59	11.59	11.59
Gross Btu/lb.	0	0	0	0	0	0	0	0	0
Bottom Ash:									
Carbon %	4.43	4.43	4.43	4.43	1.38	1.38	1.38	1.38	1.38
Gross Btu/lb.	0	0	0	0	0	0	0	0	0

TABLE 3-7. SUMMARY OF BOILER EFFICIENCY CALCULATIONS FOR SITE 4 COAL FIRED SPREADER STOKER BOILER

Test No. Date	4-1 8/11/79	4-2 8/11/79	4-3 8/13/79	4-4 8/14/79	4-5 9/6/79	4/6 9/7/79	4-7 9/8/79	4-8 9/10/79	4-9 9/11/79
Test Load									
10^3 lb. steam/hr.	94.5	96	93.5	94	95	95.5	88	94	95
MW	27.7	28.1	27.4	27.5	27.8	28.0	25.8	27.5	27.8
% of Capacity	73	74	72	72	73	73	68	72	73
Test Conditions									
Stack O_2, %	8.9	9.5	8.5	8.45	8.82	8.71	8.82	8.5	8.96
Stack CO_2, %	10.4	10.4	11.3	11.2	10.95	10.95	10.74	11.04	10.31
Stack T (K/°F)	430/315	430/315	432/317.5	426/307.5	439/330	435/323	430/314	436/326	430/314
FD Fan T (K/°F)	309/96.5	310/98	306/90.5	306/91.5	305/90	308/94	309/97	305/88.5	307/93
Boiler Heat Losses (in %)									
Dry Gas	7.22	7.12	6.63	6.48	7.40	6.98	6.73	7.30	7.19
Moisture in Fuel	3.41	3.41	3.02	2.92	2.93	2.89	2.87	3.08	2.68
Moisture from H_2	4.15	4.15	4.14	4.07	4.11	4.20	4.17	4.19	4.05
Combustibles	0	0	0	0	0	0	0	0	0
Radiation	.75	.75	.75	.75	.75	.75	.75	.75	.75
Total Losses	15.53	15.42	14.55	14.22	15.19	14.81	14.52	15.32	14.67
Boiler Efficiency, %	84.47	84.58	85.45	85.78	84.81	85.19	85.48	84.68	85.33

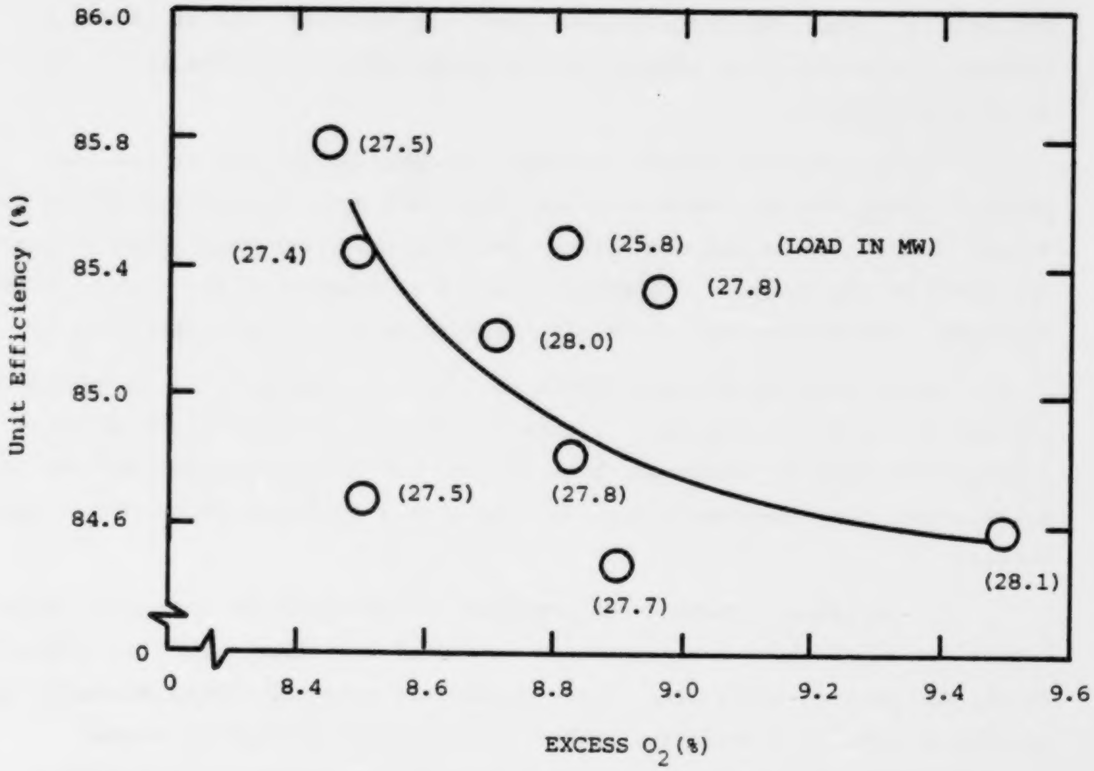


Figure 3-7. Unit Efficiency as a Function of Excess O_2 Site 4, Coal-Fired Spreader Stoker.

3.2.5 Data Reduction

The gaseous emissions data measured by the analyzers were recorded on strip chart recorders as described earlier. Additionally, an automatic data logger was also used for this 30-day test. The data logger produces printed hourly averages which are synthesized from approximately 900 spot readings. These hourly averages were then keypunched for computer data input.

Strip chart records were collected from the recorders along with copies of the appropriate control room data logs. The recorder charts were reviewed to detect any possible data gaps. In addition, the strip chart records were verified by comparison with measurements recorded by a technician on an hourly basis.

A tabulation of hourly averages was compiled for the entire test period. After the data were compiled, they were spot checked and edited to detect obvious errors and anomalies. The data were then keypunched on cards for input to the computer. Figure 3-8 shows an example of the list of hourly averages. The entire list of hourly averages is presented in Appendix F.

After data editing was completed, 24-hour averages were calculated by the use of a computer program. Figure 3-9 shows a summary of the 24-hour averages for Site 4. Although these 24-hour and hourly averages are statistically sound, they inherently tend to conceal the transient emissions of the boiler.

A statistical summary was prepared to determine the following parameters for the 24-hour averages: mean, standard deviation, maximum, minimum, range, and average deviation. These parameters were calculated assuming the data were normally distributed. When the data were plotted on normal probability paper it was apparent that they were not normally distributed. Further analysis indicated that the data were log-normally distributed. The graph shown in Figure 3-10 illustrates the performance of the coal-fired spreader stoker based on the 24-hour averages. The data points that are plotted are found in Table 3-8. The mean NO emission rate is 211 ng/J with a geometric dispersion of 1.06. The data show that 99 percent of the time the NO emissions were less than 245 ng/J.

```
******************************************************************
**                         HOURLY DATA                          **
**                 DRY STACK GAS CONCENTRATION                  **
**                                                              **
**                            O2    CO2      NO      NO      NO   **
**                  LOAD   VOL%   VOL%    PPMV    PPMV    NG/J   **
**   DATE    TIME   MWTH   MEAS   MEAS    MEAS    3%O2           **
******************************************************************
** 0/ 0/79     0     .0     .0     .0      0.      0.      0.   **
** 0/ 0/79     0     .0     .0     .0      0.      0.      0.   **
** 0/ 0/79     0     .0     .0     .0      0.      0.      0.   **
** 0/ 0/79     0     .0     .0     .0      0.      0.      0.   **
** 0/ 0/79     0     .0     .0     .0      0.      0.      0.   **
** 0/ 0/79     0     .0     .0     .0      0.      0.      0.   **
** 0/ 0/79     0     .0     .0     .0      0.      0.      0.   **
** 0/ 0/79     0     .0     .0     .0      0.      0.      0.   **
** 0/ 0/79     0     .0     .0     .0      0.      0.      0.   **
** 0/ 0/79     0     .0     .0     .0      0.      0.      0.   **
** 0/ 0/79     0     .0     .0     .0      0.      0.      0.   **
** 8/11/79  1200   23.4    8.5   13.4    191.    276.    162.   **
** 8/11/79  1300   27.2    9.0   10.2    284.    427.    251.   **
** 8/11/79  1400   28.4    8.9   10.4    281.    419.    246.   **
** 8/11/79  1500   26.4    8.9   10.3    286.    427.    250.   **
** 8/11/79  1600   28.4    9.3   10.4    291.    449.    264.   **
** 8/11/79  1700   28.1    9.1   10.4    273.    414.    243.   **
** 8/11/79  1800   27.8    9.5   10.4    291.    457.    268.   **
** 8/11/79  1900   26.1    9.6   10.4    302.    478.    281.   **
** 8/11/79  2000   28.4    8.6   10.8    282.    410.    241.   **
** 8/11/79  2100   19.0    9.2    8.9    190.    291.    171.   **
** 8/11/79  2200   17.9    9.6    9.0    199.    315.    185.   **
** 8/11/79  2300   17.0   10.5    8.3    201.    346.    203.   **
** 8/11/79  2400   17.9   10.6    8.3    203.    353.    207.   **
******************************************************************
```

Figure 3-8. Format of hourly emissions data, Site 4 Coal-Fired Spreader Stoker.

```
*********************************************************************
**                      24 HOUR DATA                               **
**              DRY STACK GAS CONCENTRATION                        **
**                                                                 **
**                            O2      CO2     NO      NO      NO   **
**                    LOAD    VOL%    VOL%    PPMV    PPMV    NG/J **
**   DATE      TIME   MWTH    MEAS    MEAS    MEAS    3%O2         **
*********************************************************************
** 8/11/79            24.6     9.3    10.1    252.    390.    229. **
** 8/12/79            19.1    10.8     8.6    219.    389.    229. **
** 8/13/79            21.7    10.0     9.6    225.    371.    218. **
** 8/14/79            21.4    10.2     9.5    204.    341.    200. **
** 8/15/79            21.2    10.5     9.2    224.    384.    225. **
** 8/16/79            21.7     9.9     9.6    221.    360.    211. **
** 8/17/79            23.0     9.5     9.7    230.    362.    212. **
** 8/18/79            22.0     9.9     9.4    227.    369.    217. **
** 8/19/79            18.3    10.8     8.3    222.    393.    231. **
** 8/20/79            24.5     9.4     9.8    241.    374.    219. **
** 8/21/79            24.0     9.2    10.0    220.    338.    198. **
** 8/22/79            23.5     9.5     9.8    235.    368.    216. **
** 8/23/79            21.7    10.4     8.9    206.    350.    206. **
** 8/24/79            21.5     9.9     9.8    221.    358.    210. **
** 8/25/79            19.5    10.5     9.1    208.    356.    209. **
** 8/26/79            18.4    10.6     8.7    195.    340.    199. **
** 8/27/79            22.9     9.9     9.6    231.    374.    220. **
** 8/28/79            24.1     9.3     9.9    225.    348.    204. **
** 8/29/79            25.9     9.1    10.4    245.    372.    218. **
** 8/30/79            24.8     9.4    10.1    235.    368.    216. **
** 8/31/79            26.8     8.7    10.7    239.    350.    206. **
** 9/ 1/79            22.7     9.7     9.9    217.    348.    204. **
** 9/ 2/79            18.5    10.5     9.1    207.    355.    208. **
** 9/ 3/79            19.1    10.3     9.5    198.    333.    196. **
** 9/ 4/79            27.2     8.8    10.8    238.    353.    207. **
** 9/ 5/79            25.7     9.1    10.4    239.    363.    213. **
** 9/ 6/79            23.4     9.7     9.9    223.    355.    208. **
** 9/ 7/79            22.2     9.7     9.7    224.    358.    210. **
** 9/ 8/79            19.8    10.1     9.1    231.    385.    226. **
** 9/ 9/79            19.1    10.2     9.1    244.    407.    239. **
** 9/10/79            23.8     9.4    10.1    241.    374.    220. **
** 9/11/79            22.8     8.8    10.4    257.    382.    224. **
** 9/12/79              .0    10.3     8.5    214.    359.    211. **
*********************************************************************
```

Figure 3-9. Summary of 24-hour Data, Site 4

TABLE 3-8. FREQUENCY DISTRIBUTION OF NO EMISSIONS AT SITE 4

Cell (ng/J)	Frequency	Cum.Freq.	%
195-200	4	4	12
201-205	2	6	18
206-210	8	14	41
211-215	4	18	53
216-220	8	26	76
221-225	2	28	82
226-230	3	31	91
231-235	1	32	94
236-240	1	33	97

$n = 33$

$\% = (\text{cum.freq.})(100)/(n+1)$

$\bar{X}$ (geometric mean) = 211 ng/J

$$g\binom{\text{geometric}}{\text{dispersion}} = \sqrt[3]{\frac{231}{194}} = 1.06$$

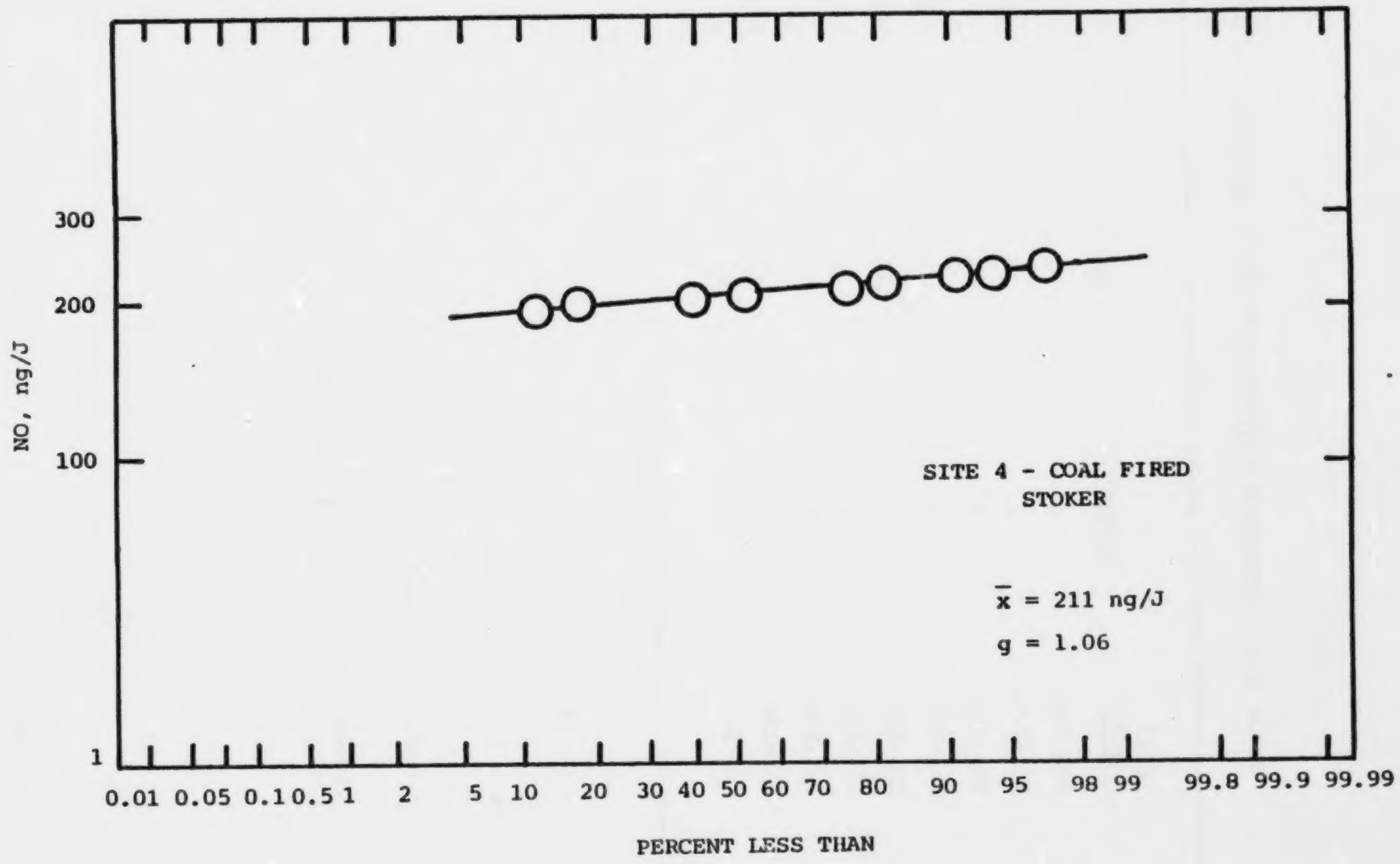


Figure 3-10. NO Emissions Site 4 Coal-Fired Spreader-Stoker.

The data were also separated into three constant load and excess O_2 ranges in which the data appeared to fall. However, the NO emissions showed an increase in geometric dispersion with both these methods of categorization.

A plot of the 24-average NO emission as a function of days from start of testing is shown in Figure 3-11. This plot shows the range of the NO measurements to be between 196 and 239 ng/J with most of the data between 200 and 220 ng/J. Excess oxygen was also plotted as a function of days from start of testing and is presented in Figure 3-12.

Observation of the hourly average data shows that during periods when KVB personnel were present, the excess oxygen was generally lower than other periods.

Operating personnel were requested to maintain the excess O_2 level as low as possible without smoking or clinkering. However, the O_2 levels tend to be somewhat higher when KVB personnel are not present. The overall O_2 level is lower than normal for the entire test period. The average excess O_2 level for 33 days was 9.8%.

Emission factors for the coal-fired stoker were calculated using the procedure set forth in 40CFR60, Subpart D. The NO emission factor (dry basis) was calculated using the following equation:

$$E = C_d F_d \frac{20.9}{20.9 - \% O_{2_d}}$$

Where E = Pollutant emission rate, ng/J (lb/million Btu)

C_d= NO concentration, ng/scm (lb/scf)

F_d= Stoichiometric conversion factor, 2.63×10^{-7} dscm/J (9,780 dscf/million Btu), for bituminous coal

O_{2_d}= Oxygen concentration, percent by volume, dry

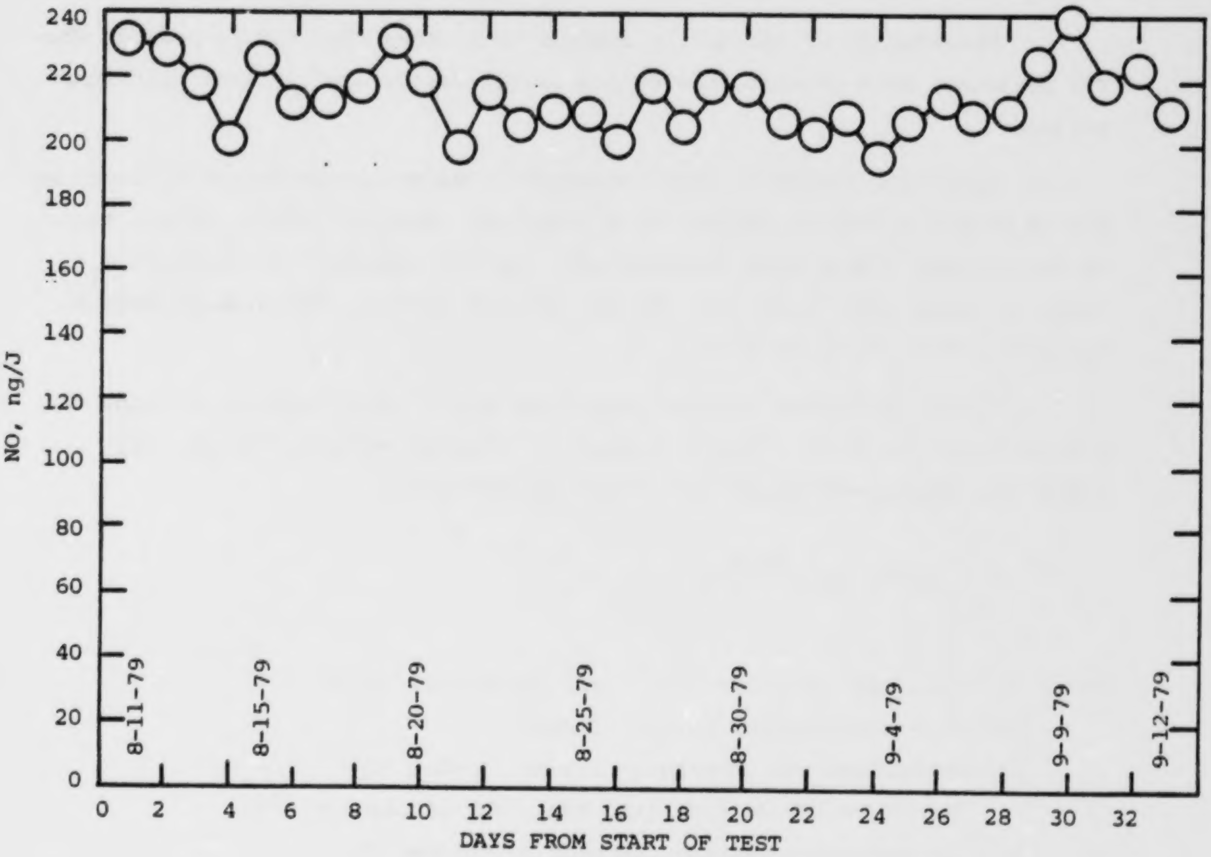


Figure 3-11. 24-Hour Average NO Emissions as a Function of Days from Start of Testing.

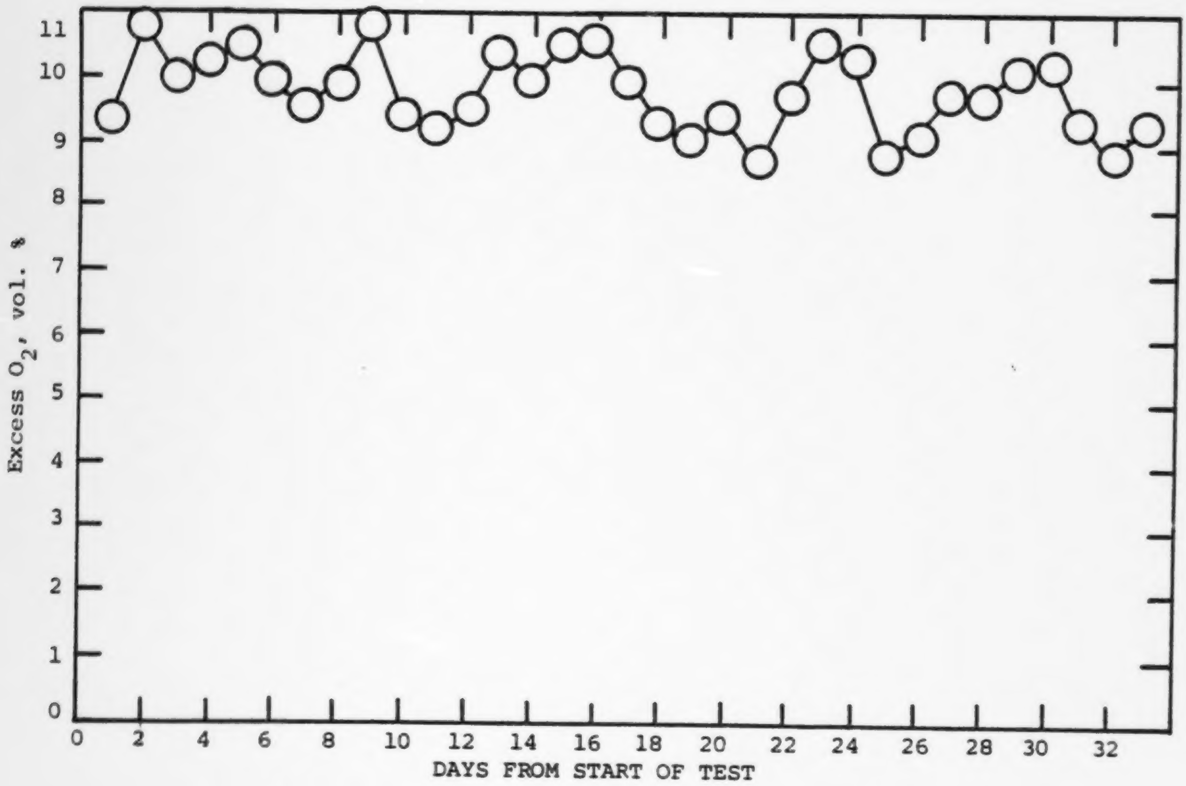


Figure 3-12. 24-Hour Average of Excess Oxygen as a Function of Days from Start of Testing.

The conversion of measured NO values (ppmv) to ng/scm is made by multiplying by $1.912\text{x}10^6$. To convert from ppm to lb/scf, multiply by $1.19\text{x}10^{-7}$. However, it should be pointed out that the stoichiometric conversion factor (F_d) is a generalized number which is based on a wide variety of bituminous coals.

NO_x emissions were measured as NO dry and the NO_x emission rates reported herein are calculated based on the molecular weight of NO_2.

SECTION 4.0

REFERENCES

1. Maloney, K. L., et al., "Systems Evaluation of the Use of Low-Sulfur Western Coal in Existing Small and Intermediate-Sized Boilers," EPA Contract No. 68-02-1863, EPA 600/7-78-153a.

2. Cato, G. A., et al., "Field Testing: Application of Combustion Modifications to Control Pollutant Emissions from Industrial Boilers - Phase I," EPA 650/2-74-078a, NTIS No. PB 238 920, June 1975.

3. Cato, G. A., et al., "Field Testing: Application of Combustion Modifications to Control Emissions from Industrial Boilers - Phase II," EPA 600/2-76-086a, NTIS No. PB 253 500, April 1976.

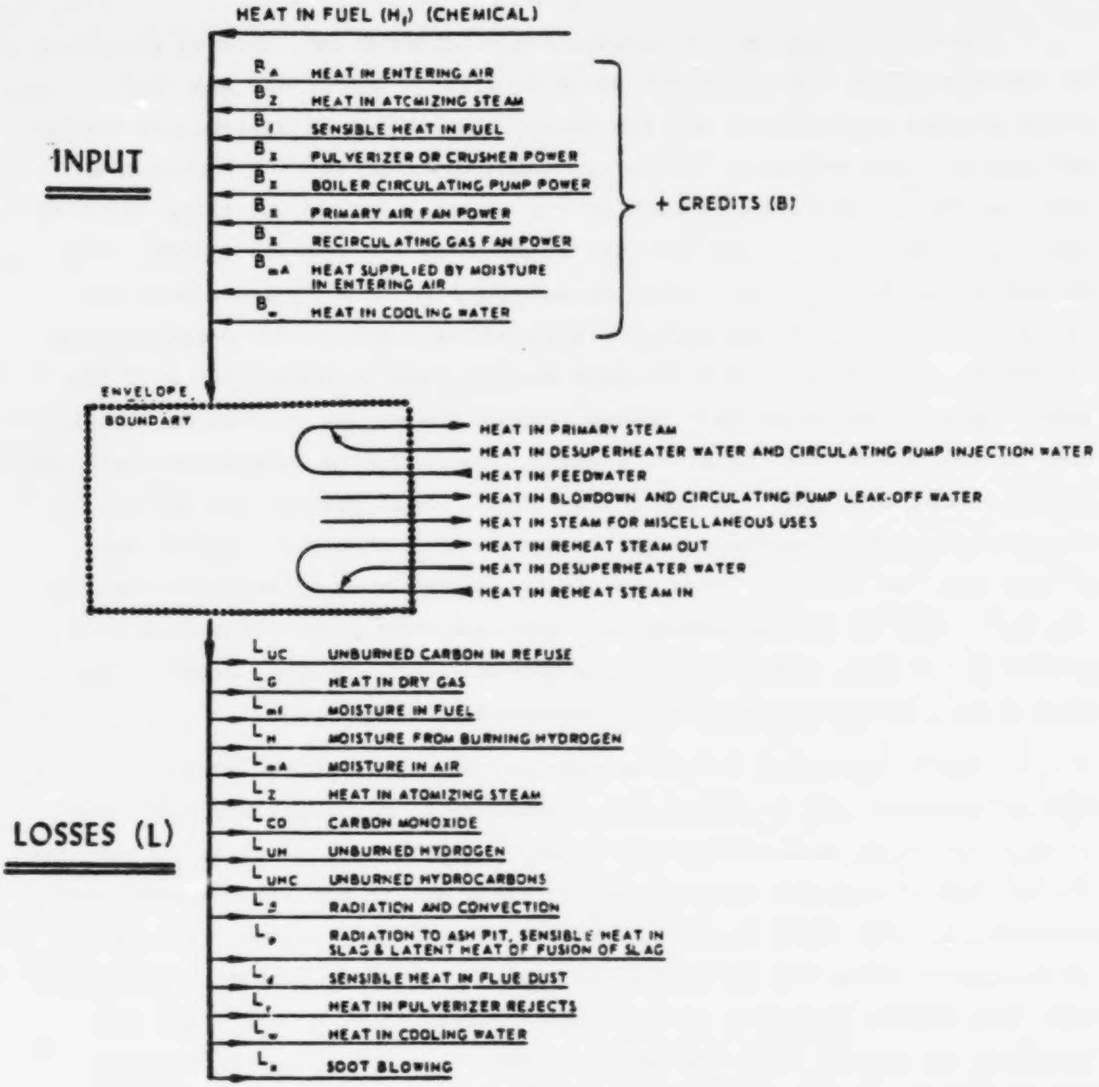
APPENDIX A

EFFICIENCY MEASUREMENTS

EFFICIENCY

Unit efficiencies for boilers are calculated and reported according to the ASME Power Test Codes for Steam Generation Units, PTC 4.1-1965. These codes present instructions for two acceptable methods of determining thermal efficiency. One method is the direct measurement of input and output and requires the accurate measurement of the quantity and high-heating value of the fuel, heat credits, and the heat absorbed by the working fluids. The second method involves the direct measurements of heat losses and is referred to as the heat loss method. This method requires the determination of losses, heat credits, and ultimate analysis and high-heat value of the fuel. Some of the major heat losses include losses due to heat in dry flue gas, losses due to fuel moisture content, losses due to combustible material in refuse and flue gas, and radiation losses. Heat credits are defined as those amounts added to the process in forms other than the chemical heat in the fuel "as fired." These include quantities such as sensible heat in the fuel, heat in the combustion air, and heat from power conversion in a pulverizer or fan. The relationships between input, output, credits, and losses for a steam generator are illustrated in Figure A-1.

KVB's experience has shown the heat-loss efficiency determination method to be the most reliable when working with industrial boilers. Accurate fuel input measurements are rarely possible on industrial boilers due to the lack of adequate instrumentation, thus making the input-output method undesirable. The accuracy of the efficiency based on the heat loss method is determined primarily by the accuracy of the flue gas temperature measurement immediately following the last heat removal station, the stack gas excess O_2 level, the fuel analysis, the ambient temperature, and proper identification of the combustion device external surfaces (for radiation losses). Determination of the radiation and other associated losses may appear to be a rather imposing calculation, but in practice it can be accomplished by utilizing standard efficiency calculation procedures. Inaccuracies in determining efficiency occasionally occur even with the heat


HEAT IN FUEL (H_f) (CHEMICAL)
INPUT
B_A HEAT IN ENTERING AIR
B_z HEAT IN ATOMIZING STEAM
B_f SENSIBLE HEAT IN FUEL
B_x PULVERIZER OR CRUSHER POWER
B_x BOILER CIRCULATING PUMP POWER
B_x PRIMARY AIR FAN POWER
B_x RECIRCULATING GAS FAN POWER
B_{mA} HEAT SUPPLIED BY MOISTURE IN ENTERING AIR
B_w HEAT IN COOLING WATER
+ CREDITS (B)
ENVELOPE BOUNDARY
HEAT IN PRIMARY STEAM
HEAT IN DESUPERHEATER WATER AND CIRCULATING PUMP INJECTION WATER
HEAT IN FEEDWATER
HEAT IN BLOWDOWN AND CIRCULATING PUMP LEAK-OFF WATER
HEAT IN STEAM FOR MISCELLANEOUS USES
HEAT IN REHEAT STEAM OUT
HEAT IN DESUPERHEATER WATER
HEAT IN REHEAT STEAM IN
LOSSES (L)
L_{UC} UNBURNED CARBON IN REFUSE
L_G HEAT IN DRY GAS
L_{mf} MOISTURE IN FUEL
L_H MOISTURE FROM BURNING HYDROGEN
L_{mA} MOISTURE IN AIR
L_z HEAT IN ATOMIZING STEAM
L_{CO} CARBON MONOXIDE
L_{UH} UNBURNED HYDROGEN
L_{UHC} UNBURNED HYDROCARBONS
L_β RADIATION AND CONVECTION
L_p RADIATION TO ASH PIT, SENSIBLE HEAT IN SLAG & LATENT HEAT OF FUSION OF SLAG
L_d SENSIBLE HEAT IN FLUE DUST
L_r HEAT IN PULVERIZER REJECTS
L_w HEAT IN COOLING WATER
L_x SOOT BLOWING

$$\text{OUTPUT} = \text{INPUT} - \text{LOSSES}$$

DEFINITION: $\text{EFFICIENCY (PERCENT)} = \eta_g (\%) = \frac{\text{OUTPUT}}{\text{INPUT}} \times 100 = \frac{\text{INPUT} - L}{H_f + B} \times 100$

HEAT BALANCE: $H_f + B = \text{OUTPUT} + L$ OR $\eta_g (\%) = \left[1 - \frac{L}{H_f + B}\right] \times 100$

Figure A-1. Heat balance of steam generator.

loss method primarily because of out-of-calibration unit instrumentation such as the stack gas exit temperature. However, this problem has been resolved by KVB test engineers through the use of portable instrumentation and separate temperature readings.

The abbreviated efficiency test procedure which considers only the major losses and the chemical heat in the fuel as input will be followed. Tables A-1 and A-2 are the ASME Test Forms for Abbreviated Efficiency Tests on steam generators which exemplify the type of forms to be used for recording the necessary data and performing the required calculations.

KVB has developed a program for the HP-67 calculator which will provide the heat loss efficiency from the stack data. Figure A-2 shows the HP-67 keyed calculation sheet for calculating efficiency by the ASME Heat Loss Method.

TABLE A-1

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

SUMMARY SHEET PTC 4.1-a(1964

TEST NO. BOILER NO. DATE
OWNER OF PLANT LOCATION
TEST CONDUCTED BY OBJECTIVE OF TEST DURATION
BOILER MAKE & TYPE RATED CAPACITY
STOKER TYPE & SIZE
PULVERIZER, TYPE & SIZE BURNER, TYPE & SIZE
FUEL USED MINE COUNTY STATE SIZE AS FIRED

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	
2	STEAM PRESSURE AT S. H. OUTLET	psia	
3	STEAM PRESSURE AT R. H. INLET	psia	
4	STEAM PRESSURE AT R. H. OUTLET	psia	
5	STEAM TEMPERATURE AT S. H. OUTLET	F	
6	STEAM TEMPERATURE AT R H INLET	F	
7	STEAM TEMPERATURE AT R. H. OUTLET	F	
8	WATER TEMP. ENTERING (ECON.) (BOILER)	F	
9	STEAM QUALITY % MOISTURE OR P. P. M.		
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	
12	TEMPERATURE OF FUEL	F	
13	GAS TEMP. LEAVING (Boiler) (Econ.) (Air Htr.)	F	
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	
16	ENTHALPY OF (SATURATED) (SUPERHEATED) STM.	Btu/lb	
17	ENTHALPY OF SAT. FEED TO (BOILER) (ECON.)	Btu/lb	
18	ENTHALPY OF REHEATED STEAM R. H. INLET	Btu/lb	
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	
20	HEAT ABS/LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	
21	HEAT ABS/LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	
27	REHEAT STEAM FLOW	lb/hr	
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	
29	TOTAL HEAT INPUT $\frac{(\text{Item 28} \times \text{Item 41})}{1000}$	kB/hr	
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	
31	TOTAL HEAT OUTPUT $\frac{(\text{Item 26} \times \text{Item 20}) + (\text{Item 27} \times \text{Item 21}) + \text{Item 30}}{1000}$	kB/hr	

FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	
33	O_2	% VOL	
34	CO	% VOL	
35	N_2 (BY DIFFERENCE)	% VOL	
36	EXCESS AIR	%	

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt
37	MOISTURE	
38	VOL MATTER	
39	FIXED CARBON	
40	ASH	
	TOTAL	
41	Btu per lb AS FIRED	
42	ASH SOFT TEMP.* ASTM METHOD	

	COAL OR OIL AS FIRED ULTIMATE ANALYSIS	
43	CARBON	
44	HYDROGEN	
45	OXYGEN	
46	NITROGEN	
47	SULPHUR	
40	ASH	
37	MOISTURE	
	TOTAL	

	COAL PULVERIZATION	
48	GRINDABILITY INDEX*	
49	FINENESS % THRU 50 M*	
50	FINENESS % THRU 200 M*	

	OIL	
51	FLASH POINT F*	
52	Sp. Gravity Deg. API*	
53	VISCOSITY AT BURNER SSU* SSF	
44	TOTAL HYDROGEN % wt	
41	Btu per lb	

	GAS	% VOL
54	CO	
55	CH_4 METHANE	
56	C_2H_2 ACETYLENE	
57	C_2H_4 ETHYLENE	
58	C_2H_6 ETHANE	
59	H_2S	
60	CO_2	
61	H_2 HYDROGEN	
	TOTAL	
	TOTAL HYDROGEN % wt	
62	DENSITY 68 F ATM. PRESS.	
63	Btu PER CU FT	
41	Btu PER LB	

64	INPUT-OUTPUT EFFICIENCY OF UNIT %	$\frac{\text{ITEM 31} \times 100}{\text{ITEM 29}}$	

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. FUEL
65	HEAT LOSS DUE TO DRY GAS		
66	HEAT LOSS DUE TO MOISTURE IN FUEL		
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2		
68	HEAT LOSS DUE TO COMBUST. IN REFUSE		
69	HEAT LOSS DUE TO RADIATION		
70	UNMEASURED LOSSES		
71	TOTAL		
72	EFFICIENCY = (100 – Item 71)		

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

TABLE A-2

PTC 4.1-b (1964)

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

CALCULATION SHEET

Revised September, 1965

OWNER OF PLANT . TEST NO. BOILER NO. DATE

30 HEAT OUTPUT IN BOILER BLOW-DOWN WATER = LB OF WATER BLOW-DOWN PER HR ×

$$\left[\frac{\overset{\text{ITEM 15}}{\ldots\ldots} - \overset{\text{ITEM 17}}{\ldots\ldots}}{1000}\right] = \ldots\ldots \text{ kB/hr}$$

24 *If impractical to weigh refuse, this item can be estimated as follows*

$$\text{DRY REFUSE PER LB OF AS FIRED FUEL} = \frac{\text{\% ASH IN AS FIRED COAL}}{100 - \text{\% COMB. IN REFUSE SAMPLE}}$$

$$\text{CARBON BURNED PER LB AS FIRED FUEL} = \frac{\overset{\text{ITEM 43}}{\ldots\ldots}}{100} - \left[\frac{\overset{\text{ITEM 22}}{\ldots\ldots} \times \overset{\text{ITEM 23}}{\ldots\ldots}}{14{,}500}\right] = \ldots\ldots$$

NOTE: IF FLUE DUST & ASH PIT REFUSE DIFFER MATERIALLY IN COMBUSTIBLE CONTENT, THEY SHOULD BE ESTIMATED SEPARATELY. SEE SECTION 7, COMPUTATIONS.

25 DRY GAS PER LB AS FIRED FUEL BURNED

$$= \frac{11CO_2 + 8O_2 + 7(N_2 + CO)}{3(CO_2 + CO)} \times \left(\text{LB CARBON BURNED PER LB AS FIRED FUEL} + \frac{3}{8}S\right)$$

$$= \frac{11 \times \overset{\text{ITEM 32}}{\ldots\ldots} + 8 \times \overset{\text{ITEM 33}}{\ldots\ldots} + 7\left(\overset{\text{ITEM 35}}{\ldots\ldots} + \overset{\text{ITEM 34}}{\ldots\ldots}\right)}{3 \times \left(\overset{\text{ITEM 32}}{\ldots\ldots} + \overset{\text{ITEM 34}}{\ldots\ldots}\right)} \times \left[\overset{\text{ITEM 24}}{\ldots\ldots} + \frac{\overset{\text{ITEM 47}}{\ldots\ldots}}{267}\right] = \ldots\ldots$$

36 EXCESS AIR †

$$= 100 \times \frac{O_2 - \frac{CO}{2}}{.2682N_2 - \left(O_2 - \frac{CO}{2}\right)} = 100 \times \frac{\text{ITEM 33} - \frac{\text{ITEM 34}}{2}}{.2682\,(\text{ITEM 35}) - \left(\text{ITEM 33} - \frac{\text{ITEM 34}}{2}\right)} = \ldots\ldots$$

	HEAT LOSS EFFICIENCY	Btu/lb AS FIRED FUEL	$\frac{\text{LOSS}}{\text{HHV}} \times 100 =$	LOSS %
65	HEAT LOSS DUE TO DRY GAS = LB DRY GAS PER LB AS FIRED FUEL $\times C_p \times (t_{lvg} - t_{air}) =$ Unit $\overset{\text{ITEM 25}}{\ldots\ldots} \times 0.24\ (\overset{\text{ITEM 13}}{\ldots\ldots}) - (\overset{\text{ITEM 11}}{\ldots\ldots}) = \ldots\ldots$	......	$\frac{65}{41} \times 100 =$	......
66	HEAT LOSS DUE TO MOISTURE IN FUEL = LB H_2O PER LB AS FIRED FUEL × [(ENTHALPY OF VAPOR AT 1 PSIA & T GAS LVG) − (ENTHALPY OF LIQUID AT T AIR)] = $\frac{\text{ITEM 37}}{100}$ × [(ENTHALPY OF VAPOR AT 1 PSIA & T ITEM 13) − (ENTHALPY OF LIQUID AT T ITEM 11)] = ...	......	$\frac{66}{41} \times 100 =$	......
67	HEAT LOSS DUE TO H_2O FROM COMB. OF $H_2 = 9H_2$ × [(ENTHALPY OF VAPOR AT 1 PSIA & T GAS LVG) − (ENTHALPY OF LIQUID AT T AIR)] = 9 × $\frac{\text{ITEM 44}}{100}$ × [(ENTHALPY OF VAPOR AT 1 PSIA & T ITEM 13) − (ENTHALPY OF LIQUID AT T ITEM 11)] = ...	......	$\frac{67}{41} \times 100 =$	......
68	HEAT LOSS DUE TO COMBUSTIBLE IN REFUSE = $\overset{\text{ITEM 22}}{\ldots\ldots} \times \overset{\text{ITEM 23}}{\ldots\ldots} = \ldots\ldots$	......	$\frac{68}{41} \times 100 =$	......
69	HEAT LOSS DUE TO RADIATION* = $\frac{\text{TOTAL BTU RADIATION LOSS PER HR}}{\text{LB AS FIRED FUEL} - \overset{\text{ITEM 28}}{\ldots\ldots}}$	......	$\frac{69}{41} \times 100 =$	......
70	UNMEASURED LOSSES **	......	$\frac{70}{41} \times 100 =$	......
71	TOTAL	......	......	......
72	EFFICIENCY = (100 − ITEM 71)	......	......	......

---

† For rigorous determination of excess air see Appendix 9.2 – PTC 4.1-1964

* If losses are not measured, use ABMA Standard Radiation Loss Chart, Fig. 8, PTC 4.1-1964

** Unmeasured losses listed in PTC 4.1 but not tabulated above may by provided for by assigning a mutually agreed upon value for Item 70.

FIGURE A-2

HP-67 KEYED CALCULATION SHEET

ASME ABBREVIATED EFFICIENCY CALCULATION - HEAT LOSS METHOD

Test No.__________ Date__________ Location____________________ Unit No.__________ Fuel__________

(Turn Calculator Off and Then On. Load Program Card.)

A. FROM FUEL ANALYSIS:

Wt. % in as-fired fuel: C __________% A1:(STO 0), Moisture __________% A2:(STO 1), H __________% A3:(STO 2), S__________% A4:(STO 3)

High heating value of fuel as-fired __________Btu/lb A5:(STO 4)

B. FROM FLUE GAS ANALYSIS:

Volume % in flue gas of: O_2 __________% B1:(STO 5), CO_2 __________% B2:(STO 6), CO __________% B3:(STO 7)

C. FROM REFUSE (FLY ASH AND ASH PIT) ANALYSIS:

C1. Fraction of dry refuse in fuel __________lbs dry refuse/lb as-fired fuel (STO 8)

C2. Heating value of dry refuse (weighted average)__________Btu/lb dry refuse (STO 9)

C3. Wt. % of combustibles in refuse __________% (f P $\gtrless$ S) (STO 4) (f P $\gtrless$ S)

D. MEASURED TEMPERATURES

D1. Gas temp. leaving boiler, econ. or air heater __________°F (STO A)

D2. Comb. air temp. __________°F (STO B)

E. FROM STEAM TABLES:

E1. Enthalpy: $H_2O(g)$ at temp. D1 & 1 psia __________Btu/lb (STO C)

E2. Enthalpy: $H_2O(l)$ at comb. air temp. __________Btu/lb (STO D)

F. FROM ABMA STANDARD RADIATION LOSS CHART (UNLESS MEASURED):

F1. Heat loss due to radiation __________% of gross heat input (STO E)

G. FROM UNIT SPECIFICATIONS (if available, otherwise enter 0):

G1. Unmeasured losses __________% of gross heat input (f P $\gtrless$ S) (STO 0) (f P $\gtrless$ S)

---

1. Excess Air $\approx \dfrac{100\ (2B1 - B3)}{0.5364(100 - B1 - B2) - (2B1 - B3)}$ (A)__________%

2. (Optional) Pounds dry gas per pound of fuel =

$$\frac{B1 + 4B2 + 700}{3(B2 + B3)} \times \left[\frac{A1}{100} - \frac{C1 \times C2}{14500\left(1 - \frac{C3}{100}\right)} + \frac{3A4}{800}\right]$$

(R/S)__________lbs dry gas/lb as-fired fuel

Heat Losses	% of Gross Heat Input	(Optional) Btu/lb as-fired fuel*
3. Due to dry gas = $\dfrac{24 \times EQ.2 \times (D1 - D2)}{A5}$	(B)__________	(R/S)__________
4. Due to moisture in fuel = $\dfrac{A2 \times (E1 - E2)}{A5}$	(C)__________	(R/S)__________
5. Due to H_2O from combustion of H_2 = $\dfrac{9 \times A3(E1 - E2)}{A5}$	(D)__________	(R/S)__________
6. Due to combustibles in refuse = $\dfrac{100 \times C1 \times C2}{A5}$	(E)__________	(R/S)__________
7. Total Losses = Sum of calculated losses + F1 + G1	(f a)__________	(R/S)__________
8. Efficiency = 100 - Total Losses	(f b)__________	

---

*Calculated as percent of gross heat input x A5 ÷ 100

APPENDIX B

DATA RECORDING FORMATS

DOCUMENTATION OF RESULTS

Field Measurements

During testing, two sets of measurements are recorded: 1) control room data which indicate the operating condition of the device and 2) emissions data that are the readouts of the individual analyzers.

The concentration of nitric oxide (NO), carbon dioxide (CO_2), carbon monoxide (CO), and oxygen (O_2) are measured and recorded. The concentration of these species are measured and displayed continuously by analyzers and strip chart recorders mounted in a console. The strip chart recordings are retained for future reference. Opacity, particulate loading, and POM concentration are measured at the sampling port and the measurements recorded on data sheets.

A number of data sheets have been developed for use in field measurements. These data sheets are listed below together with their purpose. An example of each sheet follows.

Figure No.	Title	Purpose
B-1	Thirty-Day Field Test Data Sheets	Record control room data
B-2	Gaseous Emissions Data	Record Gaseous Emissions Analyzer data
B-3	Nozzle Size, Q_m and ΔH Calculations	Calculate nozzle size, flow rate, and ΔH for Method 5 Test
B-4	Response Time for Continuous Instruments	Continuous monitor certification
B-5	Zero and Calibration Drift (24 hr)	Continuous monitor certification
B-6	Zero and Calibration Drift (2 hr)	Continuous monitor certification
B-7	Accuracy Determination (NOx)	Continuous monitor certification
B-8	Calibration Error Determination	Continuous monitor certification

Figure No.	Title	Purpose
B-9	Analysis of Calibration Gas Mixture	Continuous monitor certification
B-10	Particulate Calculation Sheet	Calculate weight of solid particulate catch
B-11	Stack Data	Record volumes, temperatures, pressures of Method 5 control unit.
B-12	Particulate Emission Caculations	Calculate particulate emmision factors
B-13	Velocity Traverse	Record temperature and velocity profile of stack
B-14	Liquid or Solid Fuel Calculation	Calculate stoichiometric properties of fuel

Figure B-1.

KVB, Inc.

THIRTY DAY FIELD TEST DATA SHEET

Site________________________ Fuel________________________

Test No.			
Date			
Time			
Load			
Test Description			
Windbox, in. H_2O			
Furnace, in. H_2O			
Overfire air, in. H_2O			
Boiler exit, in. H_2O			
Economizer exit, in. H_2O			
ID fan inlet, in. H_2O			
Steam flow, kpph			
Integrated steam flow Time/ k lbs			
Air flow indic.			
Superheater outlet temp. °F			
Flue gas temp, economizer inlet, °F			
Flue gas temp, economizer outlet, °F			
Temp F.W. economizer outlet, °F			
Feed Water Control, %			
Temp F.W. heater, °F			
F.W. economizer inlet, °F			
Steam pressure, psig			
Fuel feed			
Overfire air damper			
F.D. fan			
F.D. fan damper			
I.D. fan			
I.D. fan damper			

(continued)

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Figure B-1. (Continued)

THIRTY DAY FIELD TEST DATA SHEET

Page 2

Test No.			
Smoke Indicator Chart			
Rotary speed			
Spill plate setting			
Grate speed			
Overfire air damper, % open			
Fuel flow, Time/lbs			
Flame observations			
Bed thickness			
General furnace appearance			
Clinkers			
Ambient air temp, °F & F.D. fan inlet temp.			

Comments:

Data Sheet 6017-26
12/12/78

Figure B-2.

KVB, INC.

GASEOUS EMISSIONS DATA

Date__________

Engr.__________

Low NO_x Control Method__________

Unit No.__________ Location__________

Fuel__________ Capacity__________

Unit Type__________ Burner Type__________

1. Test No.					
2. Time					
3. Load					
4. Process Rate					
5. Flue Diam. or Size, ft					
6. Probe Position					
7. Oxygen (%)					
8. NO_x (hot) read/3% O_2 (ppm)					
9. NO (hot) read/3% O_2 (ppm)					
10. NO_2 (hot) read/3% O_2 (ppm)					
11. Carbon Dioxide (%)					
12. Carbon Monoxide (ppm) uncor/cor					
13. Opacity					
14. Atmos. Temp. (°F/°C)					
15. Dew Point Temp. (°F/°C)					
16. Atmos. Pressure (in. Hg)					
17. Relative Humidity (%)					

Data Sheet
6015-23
9/29/78

Figure B-3.

HP-67 Keyed Calculation Sheet

NOZZLE SIZE, Q_m and ΔH CALCULATIONS

Test No.__________ Date__________ Location__________

Unit No.__________ Fuel__________ Sampling Method__________

Crew: Engr.__________ Techs.__________

DATA

Constants		Key
Pitot Factor, F_s	______	(STO 1)
Orifice Factor, J	______	(STO 2)
Orifice Diam., D_o (in.)	______	(STO 3)
Ideal Meter Flow, Q_n (ACFM)	______	(STO 4)

Actual Conditions		Key
Meter Temperature, T_m(°F)	______	(STO 5)
Barom. Press., P_{Bar} (in. Hg)	______	(STO 6)
Static Press. Diff., ΔP_s (iwg)	______	(STO 7)
Nozzle Temp., T_n (°F)	______	(STO 8)
Stack Vel. Press., Δp (iwg)	______	(STO 9)

NOTE: TO RECALCULATE IDEAL NOZZLE SIZE, RESTORE DATA IN REGISTERS 4 THRU 8, CLEAR STACK AND RE-ENTER % H_2O, % O_2, and % CO_2

Gaseous Stack Composition

% H_2O	(%)	______	ENTER
% O_2 dry	(%)	______	ENTER
% CO_2 dry	(%)	______	

IDEAL NOZZLE CALCULATION

(A) Ideal Nozzle Size, $D_{n(Ideal)}$ ______ inches

METER FLOW RATE AND ORIFICE PRESS. DIFF. CALCULATIONS

Actual Nozzle Size, $D_{n(Actual)}$ ______ inches

(C) Actual Meter Flow Rate, $Q_{m(Actual)}$ ______ ACFM (on meter)

(RCL 7) Orifice Press. Diff., ΔH to obtain $Q_{m(Actual)}$ ______ iwg

NOTE: To Determine Q_m and ΔH for Other Actual Nozzle Size, Key in $D_{n(Actual)}$, Press C for Q_m, then RCL 7 for ΔH.

For one $D_{n(Actual)}$ with Changing Stack Velocity Pressure (Δp) and Nozzle Temperature (T_n)
(It is not necessary to restore data in registers 4-8 for these calculations)

Δp (ENTER) (iwg)	T_n (°F)	(E) Q_m (ACFM)	(R/S) $\Delta H'$ (iwg)

EQUATIONS

(1) $M_d = 1/25\ (4\ \%\ CO_2 + \%\ O_2) + 28$ (lb/lb mole)

(2) $M_s = M_d \left(\frac{\%\ H_2O - 100}{-100}\right) + \frac{18}{100}\ (\%\ H_2O)$ (lb/lb mole)

(3) $P_s = 13.6\ P_{Bar} + \Delta P_s$ (in. of water)

(4) $V_n = 18892\ F_s \sqrt{(\Delta p\ (T_n + 460))/P_s\ M_s}$ (ft/min)

(5) $$Q_n = \frac{Q_{m(Ideal)}\ (T_n + 460)\ 13.6\ P_{Bar}\ [828475\ \pi^2 J^2 D_o^{\ 4}\ (T_m + 460)]}{[1 - (\%\ H_2O/100)](T_m + 460)\ P_s[828475\ \pi^2 J^2 D_o^{\ 4}\ (T_m + 460) - 768\ M_d\ Q^2_{m(Ideal)}]}$$ (ACFM)

(6) $D_{n(Ideal)} = \sqrt{183.35\ (Q_n/V_n)}$ (in.)

(7) $Q_{n(Actual)} = [V_n\ D^2_{n(Actual)}]/183.35$ (ACFM)

(8) $$Q_{m_i} = \frac{Q_{n(Actual)}\ (T_m + 460)(1 - \%\ H_2O/100)(13.6\ P_{Bar} + \Delta P_s)}{(T_n + 460)(13.6\ P_{Bar} + \Delta H_{i-1})}$$ assume $\Delta H_o = \Delta P_s$ (ACFM)

$i = 1,n$ where n = number of iterations to obtain ΔH_i s.t. $\frac{(\Delta H_{i-1} - \Delta H_i)}{\Delta H_{i-1}} \leq 0.001$

(9) $$\Delta H_i = \frac{768\ Q_{m_i}^{\ 2}\ M_d\ 13.6\ P_{Bar}}{828475\ \pi^2 J^2 D_o^{\ 4}\ (T_m + 460) - 768\ Q_{m_i}^{\ 2}\ M_d}$$ (in. of water)

Figure B-4.

KVB

Engineer ______________

MONITOR PERFORMANCE TEST DATA SHEET

RESPONSE TIME FOR CONTINUOUS INSTRUMENTS

Date of Test ____________

Span Gas Concentration _________ppm

Analyzer Span Setting __________ppm

Upscale

1 _________seconds

2 _________seconds

3 _________seconds

Average upscale response ________seconds

Downscale

1 _________seconds

2 _________seconds

3 _________seconds

Average downscale response ________seconds.

System average response time (slower time) = ___________seconds.

$$\text{\% deviation from slower system average response} = \left[\frac{\text{average upscale minus average downscale}}{\text{slower time}}\right] \times 100\% = \_\_\_\_.$$

Figure B-5.

KVB

Engineer______________

MONITOR PERFORMANCE TEST DATA SHEET

ZERO AND CALIBRATION DRIFT (24-HOUR)

Date and Time	Zero Reading	Zero Drift (ΔZero)	Span Reading (After Zero Adjustment)	Calibration Drift (ΔSpan)

Zero Drift = [Mean Zero Drift* ________ + C.I. (Zero) ________]

÷ [Instrument Span] x 100 = ________.

Calibration Drift = [Mean Span Drift* ________ + C.I. (Span) ________]

÷ [Instrument Span] x 100 = ________.

*Absolute Value

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Figure B-6.

MONITOR PERFORMANCE TEST DATA SHEET

ZERO AND CALIBRATION DRIFT (2 HOUR)

Engineer________________

Data Set No.	Time		Date	Zero Reading	Zero Drift (ΔZero)	Span Reading	Span Drift (ΔSpan)	Calibration Drift (Span-Zero)
	Begin	End						
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

Zero Drift = [Mean Zero Drift* ________ + CI (Zero) ________] ÷ [Span] x 100 = ________.

Calibration Drift = [Mean Span Drift* ________ + CI (Span) ________] ÷ [Span] x 100 = ________.

*Absolute Value.

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Figure B-7.

KVB

MONITOR PERFORMANCE TEST DATA SHEET

ACCURACY DETERMINATION (NO_x)

Engineer_______________

Test No.	Date and Time	Reference Method Samples				Analyzer 1-Hour Average (ppm)* NO_x		Difference (ppm) NO_x	
		NO_x Sample 1 (ppm)	NO_x Sample 2 (ppm)	NO_x Sample 3 (ppm)	NO_x Sample Average (ppm)				
1									
2									
3									
4									
5									
6									
7									
8									
9									

Mean reference method test value (NO_x) ____________

Mean of the differences ____________

95% Confidence intervals = ± __________ ppm (NO_x)

$$\text{Accuracies} = \frac{\text{Mean of the differences + 95\% confidence interval}}{\text{Mean reference method value}} \times 100 = \_\_\_\_\_\_\% \ (NO_x)$$

* Explain and report method used to determine integrated averages

Data Sheet 6017-32

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Figure B-8.

KVB

Engineer______________

MONITOR PERFORMANCE TEST DATA SHEET

CALIBRATION ERROR DETERMINATION

Calibration Gas Mixture Data

Mid (50%) ______ppm High (90%) ______ppm

Run #	Calibration Gas Concentration, ppm	Measurement System Reading, ppm	Differences[1], ppm
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

	Mid	High
Mean difference	______	______
Confidence interval	± ______	± ______
Calibration error = $\frac{\text{Mean Difference}^{[2]} + \text{C.I.}}{\text{Average Calibration Gas Concentration}} \times 100$	______%	______%

---

[1] Calibration gas concentration - measurement system reading

[2] Absolute value

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Figure B-9.

KVB

Engineer________________

MONITOR PERFORMANCE TEST DATA SHEET

ANALYSIS OF CALIBRATION GAS MIXTURES

Date:__________________________ **Reference Method Used:**________

Mid-Range Calibration Gas Mixture

Sample 1 ______________________ppm

Sample 2 ______________________ppm

Sample 3 ______________________ppm

Average ______________________ppm

High-Range (span) Calibration Gas Mixture

Sample 1 ______________________ppm

Sample 2 ______________________ppm

Sample 3 ______________________ppm

Average ______________________ppm

Figure B-10.

PARTICULATE CALCULATION SHEET

Test Crew________________

Test No.____________ Date____________ Location______________________________

Box No.____________ Sample Probe Position______________________________

Test Description

Dry Gas Meter Vol. (ft^3)

Final ________

Initial ________

Total ________

Impinger Water Vol (ml)

	1	2	3	S. Gel	Total
Final					
Initial					
Δ Vol					

Beaker No.						Filter No.	Blank No.
Date Weighed							
Tare Wt. 1							
2							
3							
4							
5							
6							
Avg							
Bottle No.							
Content	Impinger (Water)	Probe (Acetone)	Probe (Water)	Cyclone (Acetone)	Flask (Dry)		
Rinse (ml)							
Date Weighed or 250 Bake							
Final Wt. 250 1							
2							
3							
4							
5							
6							
Avg							
Residue wt Final 250-Tare							
Date Weighed or 650 Bake							
Final Wt. 650 1							
2							
3							
4							
5							
6							
Avg							
Residue Wt Final 650-Tare							

Comments:

Data Sheet 6002-3

Figure B-11.

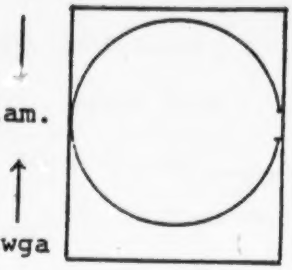
K V B, INC.

Test No._____
Engr.________

STACK DATA

Date__________ Location__________ Unit No.__________ Fuel__________
Load__________ K#/hr or MBtu/hr Filter No.________
Sample Box No._____ Meter Box No._____ Probe No._____ Probe Length_____

Filter Heater Setting _____
Probe Heater Setting _____
Stack Moisture _____ %
Ambient Temperature _____ °F
Nozzle Diameter _____ in.
Atmospheric Pressure _____ in.Hg
Weather __________
Stack Gas Pressure, Ps _____ iwg
Abs. Stack Press., AP=P_s+407=_____ iwga
Stack Gas Sp. Gravity, Gs_____ n.d.
Stack Area, As _____ ft^2



Remarks

Final Meter: __________
Initial Meter: __________

Time	Vm Meter Volume Reading (CF)	Vacuum Gage Reading (iwg)	ΔP Pitot Tube Pressure (iwg)	H Orfice Pressure Diff (°F)	Stack Temp. (°F)	Impinger Temperature		Filter Box Temp. (°F)	Meter Temp. (°F)
						Out (°F)	In (°F)		
Total					°F				
Avg.					°F				
					+ 460				

Ts= ______ °R

HP-67 KEYED CALCULATION SHEET*

Figure B-12.

PARTICULATE EMISSION CALCULATIONS

Test No.____________ Date____________ Location________________________ Engr.__________

Unit No.____________ Fuel____________ Sampling Train and Method ____________________

Pitot Factor, Fs .83 Barometric Pressure, P_{bar} ____________ (STO 0) in. Hg

Tot. Liquid Collected, V_{lc} ____________ (STO 1) ml Total Particulate, M_n ____________ (STO 2) m gm

Velocity Head, ΔP __________ (STO 3) iwg Stack Temp., Ts __________ (STO 4) °F Stack Area, As __________ (STO 5) ft^2

Sample Volume, Vm __________ (STO 6) ft^3 Stack Press., Psg __________ (STO 7) iwg Excess O_2, XO_2% __________ (STO 8) %

Orifice Press. Diff., H __________ (STO 9) iwg, (Flue Gas Density/Air Density) @ T_s, Gs __________ (STO A) n.d.

Sample Time, θ __________ (STO B) min Nozzle Dia., Dn __________ (STO C) in. Meter Temp., T_m __________ (STO D) °F

Select F_e	Oil (A)	Gas (B)	Coal (C)	Other:
SC Feet/10^4 Btu	92.2	87.4	98.2	(D)

Press (E) if meter is not temperature compensated.

1. Sample Gas Volume $Vm_{std} = 0.0334\ Vm(P_{bar} + H/13.6)$ ____________ SCF
2. Water Vapor $Vw_{std} = 0.0474\ V_{lc}$ ____________ SCF
3. Moisture Content $Bwo = \text{Eq. } 2/(\text{Eq. } 1 + \text{Eq. } 2)$ ____________ N.D.
4. Concentration a. $C = 0.0154\ Mn/Vm_{std}$ ____________ grains/DSCF

   b. $C = 2.205 \times 10^{-6}\ Mn/Vm_{std}$ ____________ lb/DSCF

   c. $C = \text{Eq. } 4b \times 16.018 \times 10^3$ ____________ grams/DSCM
5. Abs. Stack Press. $Ps = P_{bar} \times 13.6 + Psg$ ____________ in. w abs.
6. Stack Gas Speed $Vs = 174\ Fs \sqrt{\Delta P Ts} \sqrt{\frac{407}{Ps} \times \frac{1.00}{Gs}}$ ____________ ft/min
7. Stack Gas Flow Rate @ 70°F a. $Qsw = \text{Eq. } 6 \times As \times \frac{530}{Ts} \times \frac{Ps}{407}$ ____________ WSCF/min

   b. $Qsd = \text{Eq. } 7a \times (1. - \text{Eq. } 3)$ ____________ DSCF/min
8. Material Flow $Ms = \text{Eq. } 7b \times \text{Eq. } 4b \times 60$ ____________ lb/hr
9. XO_2 factor $XO_2f = 2090/(20.9 - XO_2\%)$ ____________ N.D.
10. Emission a. $E = \text{Eq. } 4b \times Fe \times \text{Eq. } 9$ ____________ lb/MMBtu

    b. $E = \text{Eq. } 4c \times Fm \times \text{Eq. } 9 \times 1000$ ____________ ng/joule
11. % Isokinetic $I = \dfrac{14077 \times Ts(Vm_{std} + Vw_{std})}{\theta \times Vs \times Ps \times Dn^2}$ ____________ %

*If calculating by hand:
1) Convert T_s and T_m to °R
2) Multiply EQ 1 by $530/T_m$(°R) if meter not temperature compensated.
3) $F_m = 2.684 \times 10^{-5} \times F_e$

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Revised 9/27/78

Figure B-13.

KVB, Inc.

VELOCITY TRAVERSE

Project:______________________ Test Description:___
Date:______________________ ______________________
Location:______________________ ______________________
Unit:______________________ ______________________
Test:______________________ Personnel:__________
Fuel:______________________ ______________________
Barometric Press. (in. Hg):______________________
Absolute Static Press. in Stack (in. Hg):__________ (P_s)
Pitot Tube Coefficient:______________________ (C_p)

$$V_S = 85.48\ C_p \left[\frac{T_S \Delta P}{P_S M_S}\right]^{1/2}$$

Stack Cross Section

Time	Traverse Point Port	 Depth	Velocity Head (in. H_2O)	Gas Temp. (°F)	Gas Temp. (°R)	Molecular Wt.	Velocity (ft/sec)	O_2 Conc. (% Dry)
			ΔP		T_S	M_S	V_S	

Figure B-14.

KVB

Test No.__________ Date______________ Location________________________ Unit No.______

Fuel____________________ Fuel Sample No.____________________ Fuel Sample Point__________

LIQUID OR SOLID FUEL CALCULATIONS

(f)(CL REG), (f) (P≷S), (f)(CL REG), Load data card, then PGRM card (both sides)

*Input HHV (Btu/lb) ______________, (A)
*Input wt % C ______________, (R/S)
*Input wt % H ______________, (R/S)
*Input wt % S ______________, (R/S)
*Input wt % O ______________, (R/S)
*Input wt % N ______________, (R/S) - decimal point blinks after pressing; item #1 displayed

1. Dry stoichiometric moles flue gas/lb fuel = ______________.
(One may proceed to items 9, 17, or 18 by pressing (f)(A), (E), or entering MW and pressing (B), respectively.)

- -

*Input wt % H_2O in fuel (0 if none) ______________

(C) 2. Moles H_2O in flue gas/lb fuel ______________
(R/S) 3. Total moles of flue gas (stoichiometric)/lb fuel ______________
(R/S) 4. Dry volume/wet volume ______________
(R/S) 5. Volume % H_2O in flue gas ______________
(R/S) 6. Volume % CO_2, dry in flue gas ______________
(R/S) 7. SO_2 (ppm by vol.), dry at stoichiometric ______________
(R/S) 8. NO (ppm by vol.), dry at stoichiometric ______________

- -

(f)(A) 9. Stoichiometric air/fuel ratio (lb air/lb fuel) ______________

- -

(Before items 10-16 may be determined, items 1-9 must be completed.)

(D) - 20.95 displayed

		*Input measured vol. % O_2 for O_2 correction	____	____	____	____
(R/S)	10.	$\frac{\text{Gas moles at \% } O_2}{\text{Gas moles, stoic.}} = \frac{20.95}{20.95 - \% O_2} =$	____	____	____	____
(R/S)	11.	Dry moles flue gas/lb fuel at % O_2	____	____	____	____
(R/S)	12.	Vol. % CO_2, dry at % O_2	____	____	____	____
(R/S)	13.	SO_2 (ppm by vol.) dry at % O_2	____	____	____	____
(R/S)	14.	NO (ppm by vol.) dry at % O_2	____	____	____	____
(R/S)	15.	Vol. % H_2O at % O_2	____	____	____	____
(R/S) (decimal pt. blinks)	16.	Percent Excess Air	____	____	____	____

- -

(RCL)(2)(E) 17. Converts item 1 to SCF dry flue gas at stoich/10^6 Btu = ______________

- -

Item 18.

a. *Input MW, (B), program calculates K (lb/10^6 Btu = ppm/K)
(MW = 46 for NOx, CO = 28, HC = 16, SOx = 64)

1. *Input measured ppm at 3% O_2, dry, (R/S), program calculates lb/10^6 Btu.
2. (Optional) No input, (R/S), program converts lb/10^6 Btu → ng/J
3. Repeat steps (1) and (2) as necessary.

b. *Enter next value of MW, complete step (a) followed by steps (1), (2), and (3). Repeat for all species desired.

	MW	K for lb/10^6 Btu
NOx	46	____
CO	28	____
HC	16	____
SOx	64	____

---

*Indicates input is required

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Revised 7/6/78

APPENDIX C

CONTINUOUS MONITOR CERTIFICATION DATA SHEETS

KVB

Engineer
8-8-79

MONITOR PERFORMANCE TEST DATA SHEET

CALIBRATION ERROR DETERMINATION

Calibration Gas Mixture Data

Mid (50%) 120 ppm   High (90%) 234 ppm

NO - Analyzer - Teco Series 10

Run #		Calibration Gas Concentration, ppm	Measurement System Reading, ppm	Differences[1], ppm
1	0	0	0	0
2	M	120	121	+1
3	0	0	0	0
4	H	234	233	-1
5	M	120	121	+1
6	H	234	234	0
7	M	120	121	+1
8	0	0	0	0
9	M	120	120	0
10	0	0	0	0
11	H	234	233	-1
12	M	120	121	+1
13	H	234	233	-1
14	0	0	0	0
15	H	234	234	0

Reading on 0-250 ppm Range

	Mid	High
	.8	.6
Mean difference	+.56	+.68
Confidence interval		
Calibration error = $\frac{\text{Mean Difference}^2 + \text{C.I.}}{\text{Average Calibration Gas Concentration}} \times 100$	1.13 %	0.55 %

---

[1] Calibration gas concentration - measurement system reading

[2] Absolute value

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KVB

Engineer K.
8-8-79

MONITOR PERFORMANCE TEST DATA SHEET

CALIBRATION ERROR DETERMINATION

Calibration Gas Mixture Data

Mid (50%) 5.0 % ~~ppm~~   High (90%) 9.3 % ~~ppm~~

Oxygen Analyzer - Beckman Model 7003

Run #	Calibration Gas Concentration, ppm	Measurement System Reading, ppm	Differences[1], ppm
1 0	No zero adjustment on analyzer		
2 M	5.0	5.1	+.1
3 0	DNA	–	–
4 H	9.3	9.1	-.2
5 M	5.0	4.9	-.1
6 H	9.3	9.2	-.1
7 M	5.0	5.0	0
8 0	DNA	–	–
9 M	5.0	5.1	+.1
10 0	DNA	–	–
11 H	9.3	9.1	-.2
12 M	5.0	5.0	0
13 H	9.3	9.1	-.2
14 0	DNA	–	–
15 H	9.3	9.1	-.2

Reading on 0 - 10 scale

	Mid	High
Mean difference	.06	.18
Confidence interval	+.068	+.056
$\text{Calibration error} = \dfrac{\text{Mean Difference}^{2} + \text{C.I.}}{\text{Average Calibration Gas Concentration}} \times 100$	2.56 %	2.54 %

---

[1] Calibration gas concentration - measurement system reading

[2] Absolute value

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KVB

Engineer ________
8-8-79

MONITOR PERFORMANCE TEST DATA SHEET

CALIBRATION ERROR DETERMINATION

Calibration Gas Mixture Data

Mid (50%) 10.0 ~~ppm~~ %   High (90%) 17.8 ~~ppm~~ %

CO2 Analyzer - Horiba PIR-2000

Run #		Calibration Gas Concentration, ppm	Measurement System Reading, ppm	Differences[1], ppm
1	0	0	0	0
2	M	10	10	0
3	0	0	0	0
4	H	17.8	17.8	0
5	M	10	10	0
6	H	17.8	17.8	0
7	M	10	10	0
8	0	0	0	0
9	H	10	10	0
10	0	0	0	0
11	H	17.8	17.8	0
12	M	10	10	0
13	H	17.8	17.8	0
14	0	0	0	0
15	H	17.8	17.8	0

Reading on 0-20% scale.

	Mid	High
Mean difference	0	0
Confidence interval	± 0	± 0
Calibration error = $\frac{\text{Mean Difference}^2 + \text{C.I.}}{\text{Average Calibration Gas Concentration}} \times 100$	0 %	0 %

---

[1] Calibration gas concentration - measurement system reading

[2] Absolute value

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NO TECO Series 10

MONITOR PERFORMANCE TEST DATA SHEET
ZERO AND CALIBRATION DRIFT (2 HOUR)

Buening & Hart

Data Set No.	Time		Date	Zero Reading	Zero Drift (ΔZero)	Span Reading	Span Drift (ΔSpan)	Calibration Drift (Span-Zero)
	Begin	End						
1	900		8-9-79	100 ppmV	—	234 ppmV	—	—
2	1100			103	3	242	8	5
3	1300			104	1	241	-1	-2
4	1500			107	3	247	6	3
5	1700			109	2	248	1	-1
6	1900			110	1	249	1	0
7	2100			106	-4	249	-1	3
8	2300		↓	104	-2	244	-4	-2
9	900		8-10-79	100	—	234	—	—
10	1100			100	0	234	0	0
11	1300			101	1	236	2	1
12	1500			101	0	237	1	1
13	1700			101	0	238	1	1
14	1900			100	-1	236	-2	-1
15	2100			101	1	237	1	0
16	2300		↓	100	-1	236	-1	0
17	900		8-11-79	100	—	234	—	—
18	1100		↓	100	0	238	4	4
19								
20								

Zero Drift = [Mean Zero Drift* 1.33 + CI (Zero) 0.68] ÷ [Span] x 100 = 0.20%.

Calibration Drift = [Mean Span Drift* 2.267 + CI (Span) 1.24] ÷ [Span] x 100 = 0.35%.

*Absolute Value.

Span = 1000

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O₂ Beckman - 7003

Buening & Hart

MONITOR PERFORMANCE TEST DATA SHEET
ZERO AND CALIBRATION DRIFT (2 HOUR)

Data Set No.	Time		Date	Zero Reading	Zero Drift (ΔZero)	Span Reading	Span Drift (ΔSpan)	Calibration Drift (Span-Zero)
	Begin	End						
1	900		8-9-79	Does Not Apply	Does Not Apply	9.27 vol %	—	Does Not Apply
2	1100					9.20	−.07	
3	1300					9.10	−.10	
4	1500					9.22	.12	
5	1700					9.20	−.02	
6	1900					9.14	−.06	
7	2100					9.06	−.08	
8	2300		↓			9.10	.04	
9	900		8-10-79			9.27	—	
10	1100					9.45	.18	
11	1300					9.25	−.20	
12	1500					9.25	0	
13	1700					9.275	.025	
14	1900					9.25	−.025	
15	2100					9.40	.15	
16	2300		↓			9.50	.10	
17	900		8-11-79			9.27	—	
18	1100		↓	↓	↓	9.27	0	↓
19								
20								

Zero Drift = [Mean Zero Drift* __—__ + CI (Zero) __—__] ÷ [Span] x 100 = __—__.

Calibration Drift = [Mean Span Drift* _.0767_ + CI (Span) _.036_] ÷ [Span] x 100 = _0.45 %_.

*Absolute Value.

Span = 25

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CO_2 Horiba-PIR 2000

Baening & Hart

MONITOR PERFORMANCE TEST DATA SHEET
ZERO AND CALIBRATION DRIFT (2 HOUR)

Data Set No.	Time		Date	Zero Reading	Zero Drift (ΔZero)	Span Reading	Span Drift (ΔSpan)	Calibration Drift (Span-Zero)
	Begin	End						
1	900		8-9-79	0.98 vol %	—	17.8 vol %	—	—
2	1100		↓	0.98	0	18	.2	.2
3	1300			0.99	.01	18	0	-.01
4	1500			0.99	0	18	0	0
5	1700			1.00	.01	18	0	-.01
6	1900			0.99	-.01	18	0	.01
7	2100			0.98	-.01	17.9	-.1	-.09
8	2300		↓	1.00	.02	17.9	0	-.02
9	900		8-10-79	0.98	—	17.8	—	—
10	1100		↓	1.05	.07	17.82	.02	-.05
11	1300			1.02	.03	17.9	.08	.05
12	1500			1.00	-.02	17.8	-.1	-.08
13	1700			1.02	.02	17.8	0	-.02
14	1900			1.00	-.02	17.8	0	.02
15	2100			1.02	.02	17.8	0	-.02
16	2300		↓	1.00	-.02	17.8	0	-.02
17	900		8-11-79	0.98	—	17.8	—	—
18	1100		↓	0.98	0	17.5	-.3	-.3
19								
20								

Zero Drift = [Mean Zero Drift* .017 + CI (Zero) .046] ÷ [Span] x 100 = 0.317 %.

Calibration Drift = [Mean Span Drift* .053 + CI (Span) .102] ÷ [Span] x 100 = 0.775 %

span = 20

*Absolute Value.

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KVB

MONITOR PERFORMANCE TEST DATA SHEET

Buening & Hart

ZERO AND CALIBRATION DRIFT (24-HOUR)

NO TECO Series 10

Date and Time	Zero Reading	Zero Drift (ΔZero)	Span Reading (After Zero Adjustment)	Calibration Drift (ΔSpan)
8-9-79 9 AM	100 ppmV	—	234 ppmV	—
8-10-79	100	0	242	8
8-11-79	100	0	234	0
8-12-79	100	0	235	1
8-13-79	102	2	236	2
8-14-79	100	0	238	4
8-15-79	102	2	237	3
8-16-79	102	2	233	−1

Zero Drift = [Mean Zero Drift* 0.86 + C.I. (Zero) 0.99]

÷ [Instrument Span] x 100 = 0.19%.

Calibration Drift = [Mean Span Drift* 2.71 + C.I. (Span) 2.49]

÷ [Instrument Span] x 100 = 0.52%.

*Absolute Value

Span = 1000

KVB

MONITOR PERFORMANCE TEST DATA SHEET

Buening & Hart

ZERO AND CALIBRATION DRIFT (24-HOUR)

O_2 Beckman - 7003

Date and Time	Zero Reading	Zero Drift (ΔZero)	Span Reading (After Zero Adjustment)	Calibration Drift (ΔSpan)
8-9-79 9AM	Does Not Apply	Does Not Apply	9.27 vol %	—
8-10-79			8.94	-.33
8-11-79			10.175	.91
8-12-79			9.7	.43
8-13-79			9.48	.21
8-14-79			9.33	.06
8-15-79			9.48	.21
8-16-79 ↓	↓	↓	9.40	.13

Zero Drift = [Mean Zero Drift* —— + C.I. (Zero) ——]

÷ [Instrument Span] x 100 = —— .

Calibration Drift = [Mean Span Drift* .33 + C.I. (Span) .26]

÷ [Instrument Span] x 100 = 2.38% .

*Absolute Value

span = 25

KVB

MONITOR PERFORMANCE TEST DATA SHEET

Buening & Hart

ZERO AND CALIBRATION DRIFT (24-HOUR)

CO_2 Horiba - PIR 2000

Date and Time	Zero Reading	Zero Drift (ΔZero)	Span Reading (After Zero Adjustment)	Calibration Drift (ΔSpan)
8-9-79 9AM	0.98 vol%	—	17.8 vol%	—
8-10-79	0.97	-.01	18.1	.3
8-11-79	1.01	.03	17.8	0
8-12-79	1.00	.02	17.6	-.2
8-13-79	1.00	.02	17.9	.1
8-14-79	1.10	.12	18.1	.3
8-15-79	1.10	.12	17.8	0
8-16-79	1.00	.02	17.8	0

Zero Drift = [Mean Zero Drift* .05 + C.I. (Zero) .042]
÷ [Instrument Span] x 100 = 0.45%.

Calibration Drift = [Mean Span Drift* .129 + C.I. (Span) .128]
÷ [Instrument Span] x 100 = 1.285%.

*Absolute Value

Span = 20

KVB

Engineer K.

MONITOR PERFORMANCE TEST DATA SHEET

RESPONSE TIME FOR CONTINUOUS INSTRUMENTS

NO Instrument

Date of Test 8-8-79

Span Gas Concentration 234 ppm

Analyzer Span Setting 250 ppm

Upscale
1 77 seconds
2 71 seconds
3 75 seconds

Average upscale response 74.3 seconds

Downscale
1 80 seconds
2 83 seconds
3 84 seconds

Average downscale response 82.3 seconds.

System average response time (slower time) = 82.3 seconds.

% deviation from slower system average response $= \left[\frac{\text{average upscale minus average downscale}}{\text{slower time}}\right] \times 100\% =$ 9.7.

KVB

Engineer K.

MONITOR PERFORMANCE TEST DATA SHEET

RESPONSE TIME FOR CONTINUOUS INSTRUMENTS

O_2 Instrument

Date of Test 8-8-79

Span Gas Concentration 9.3 % ~~ppm~~

Analyzer Span Setting 10 % ~~ppm~~

Upscale	1	68 seconds
	2	70 seconds
	3	71 seconds

Average upscale response 69.7 seconds

Downscale	1	73 seconds
	2	74 seconds
	3	73 seconds

Average downscale response 73.3 seconds.

System average response time (slower time) = 73.3 seconds.

% deviation from slower system average response $= \left[\frac{\text{average upscale minus average downscale}}{\text{slower time}}\right] \times 100\% = 4.9$.

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Engineer K.

MONITOR PERFORMANCE TEST DATA SHEET

RESPONSE TIME FOR CONTINUOUS INSTRUMENTS

CO2 Instrument

Date of Test 8-8-79

Span Gas Concentration 17.8 % ~~ppm~~

Analyzer Span Setting 20 % ~~ppm~~

Upscale	1	95 seconds
	2	93 seconds
	3	93 seconds
	Average upscale response	93.7 seconds
Downscale	1	97 seconds
	2	95 seconds
	3	98 seconds
	Average downscale response	96.7 seconds.

System average response time (slower time) = 96.7 seconds.

% deviation from slower system average response $= \left[\frac{\text{average upscale minus average downscale}}{\text{slower time}}\right] \times 100\% =$ 3.1%

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MONITOR PERFORMANCE TEST DATA SHEET

ACCURACY DETERMINATION (NO_x)

Engineer J. HART

Test No.	Date and Time	Reference Method Samples				Analyzer 1-Hour Average (ppm)* NO_x @3% O_2, DRY		Difference (ppm) NO_x @3% O_2, DRY	
		NO_x Sample 1 (ppm) @3% O_2, DRY	NO_x Sample 2 (ppm) @3% O_2, DRY	NO_x Sample 3 (ppm) @3% O_2, DRY	NO_x Sample Average (ppm) @3% O_2, DRY				
1	8-11-79 1130	433	432	401	422		393		29
2	8-11-79 1230	493	483	499	492		467		25
3	8-11-79 1330	495	495	469	486		480		6
4	8-11-79 1430	514	458	440	474		476		2
5	8-11-79 1530	457	467	459	461		490		29
6	8-11-79 1630	493	445	446	461		464		3
7	8-11-79 1730	519	511	482	504		475		29
8	8-11-79 1830	487	495	513	498		513		15
9	8-11-79 1930	473	454	470	466		530		64

Mean reference method test value (NO_x) 474

Mean of the differences 22

95% Confidence intervals = ± 14.85 ppm (NO_x)

Accuracies = $\frac{\text{Mean of the differences + 95\% confidence interval}}{\text{Mean reference method value}}$ x 100 = 7.77 % (NO_x)

* Explain and report method used to determine integrated averages

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MONITOR PERFORMANCE TEST DATA SHEET

ACCURACY DETERMINATION (NO_x)

Engineer Y. HART

Test No.	Date and Time	Reference Method Samples NO_x Sample 1 (ppm) @ 3% O_2, DRY	 NO_x Sample 2 (ppm) @ 3% O_2, DRY	 NO_x Sample 3 (ppm) @ 3% O_2, DRY	 NO_x Sample Average (ppm) @ 3% O_2, DRY	Analyzer 1-Hour Average (ppm)* NO_x @ 3% O_2, DRY		Difference (ppm) NO_x @ 3% O_2, DRY	
1	9-10-79 830	439	422	405	422		406		16
2	9-10-79 930	414	384	370	389		383		6
3	9-10-79 1030	415	412	413	413		400		13
4	9-10-79 1130	Air Leak	Low Sample	339	339		278		61
5	9-10-79 1230	342	350	363	352		332		20
6	9-10-79 1330	381	367	357	368		359		9
7	9-10-79 1430	392	374	387	384		375		9
8	9-10-79 1530	379	385	386	383		409		26
9	9-10-79 1630	408	437	391	412		378		34

Mean reference method test value (NO_x) 385

Mean of the differences 22

95% Confidence intervals = ± 13.3 ppm (NO_x)

$$\text{Accuracies} = \frac{\text{Mean of the differences + 95\% confidence interval}}{\text{Mean reference method value}} \times 100 = \underline{9.17}\ \%\ (NO_x)$$

* Explain and report method used to determine integrated averages

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APPENDIX D

CONTINUOUS MONITOR PERFORMANCE SPECIFICATIONS

PERFORMANCE SPECIFICATION 2—PERFORMANCE SPECIFICATIONS AND SPECIFICATION TEST PROCEDURES FOR MONITORS OF SO$_2$ AND NO$_x$ FROM STATIONARY SOURCES

1. Principle and Applicability.

1.1 Principle. The concentration of sulfur dioxide or oxides of nitrogen pollutants in stack emissions is measured by a continuously operating emission measurement system. Concurrent with operation of the continuous monitoring system, the pollutant concentrations are also measured with reference methods (Appendix A). An average of the continuous monitoring system data is computed for each reference method testing period and compared to determine the relative accuracy of the continuous monitoring system. Other tests of the continuous monitoring system are also performed to determine calibration error, drift, and response characteristics of the system.

1.2 Applicability. This performance specification is applicable to evaluation of continuous monitoring systems for measurement of nitrogen oxides or sulfur dioxide pollutants. These specifications contain test procedures, installation requirements, and data computation procedures for evaluating the acceptability of the continuous monitoring systems.

2. Apparatus.

2.1 Calibration Gas Mixtures. Mixtures of known concentrations of pollutant gas in a diluent gas shall be prepared. The pollutant gas shall be sulfur dioxide or the appropriate oxide(s) of nitrogen specified by paragraph 6 and within subparts. For sulfur dioxide gas mixtures, the diluent gas may be air or nitrogen. For nitric oxide (NO) gas mixtures, the diluent gas shall be oxygen-free (<10 ppm) nitrogen, and for nitrogen dioxide (NO$_2$) gas mixtures the diluent gas shall be air. Concentrations of approximately 50 percent and 90 percent of span are required. The 90 percent gas mixture is used to set and to check the span and is referred to as the span gas.

2.2 Zero Gas. A gas certified by the manufacturer to contain less than 1 ppm of the pollutant gas or ambient air may be used.

2.3 Equipment for measurement of the pollutant gas concentration using the reference method specified in the applicable standard.

2.4 Data Recorder. Analog chart recorder or other suitable device with input voltage range compatible with analyzer system output. The resolution of the recorder's data output shall be sufficient to allow completion of the test procedures within this specification.

2.5 Continuous monitoring system for SO$_2$ or NO$_x$ pollutants as applicable.

3. Definitions.

3.1 Continuous Monitoring System. The total equipment required for the determination of a pollutant gas concentration in a source effluent. Continuous monitoring systems consist of major subsystems as follows:

3.1.1 Sampling Interface. That portion of an extractive continuous monitoring system that performs one or more of the following operations: Acquisition, transportation, and conditioning of a sample of the source effluent or that portion of an in-situ continuous monitoring system that protects the analyzer from the effluent.

3.1.2 Analyzer. That portion of the continuous monitoring system which senses the pollutant gas and generates a signal output that is a function of the pollutant concentration.

3.1.3 Data Recorder. That portion of the continuous monitoring system that provides a permanent record of the output signal in terms of concentration units.

3.2 Span. The value of pollutant concentration at which the continuous monitoring system is set to produce the maximum data display output. The span shall be set at the concentration specified in each applicable subpart.

3.3 Accuracy (Relative). The degree of correctness with which the continuous monitoring system yields the value of gas concentration of a sample relative to the value given by a defined reference method. This accuracy is expressed in terms of error, which is the difference between the paired concentration measurements expressed as a percentage of the mean reference value.

3.4 Calibration Error. The difference between the pollutant concentration indicated by the continuous monitoring system and the known concentration of the test gas mixture.

3.5 Zero Drift. The change in the continuous monitoring system output over a stated period of time of normal continuous operation when the pollutant concentration at the time for the measurements is zero.

3.6 Calibration Drift. The change in the continuous monitoring system output over a stated time period of normal continuous operations when the pollutant concentration at the time of the measurements is the same known upscale value.

3.7 Response Time. The time interval from a step change in pollutant concentration at the input to the continuous monitoring system to the time at which 95 percent of the corresponding final value is reached as displayed on the continuous monitoring system data recorder.

3.8 Operational Period. A minimum period of time over which a measurement system is expected to operate within certain performance specifications without unscheduled maintenance, repair, or adjustment.

3.9 Stratification. A condition identified by a difference in excess of 10 percent between the average concentration in the duct or stack and the concentration at any point more than 1.0 meter from the duct or stack wall.

4. Installation Specifications. Pollutant continuous monitoring systems (SO$_2$ and NO$_x$) shall be installed at a sampling location where measurements can be made which are directly representative (4.1), or which can be corrected so as to be representative (4.2) of the total emissions from the affected

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facility. Conformance with this requirement shall be accomplished as follows:

4.1 Effluent gases may be assumed to be nonstratified if a sampling location eight or more stack diameters (equivalent diameters) downstream of any air in-leakage is selected. This assumption and data correction procedures under paragraph 4.2.1 may not be applied to sampling locations upstream of an air preheater in a steam generating facility under Subpart D of this part. For sampling locations where effluent gases are either demonstrated (4.3) or may be assumed to be nonstratified (eight diameters), a point (extractive systems) or path (in-situ systems) of average concentration may be monitored.

4.2 For sampling locations where effluent gases cannot be assumed to be nonstratified (less than eight diameters) or have been shown under paragraph 4.3 to be stratified, results obtained must be consistently representative (e.g. a point of average concentration may shift with load changes) or the data generated by sampling at a point (extractive systems) or across a path (in-situ systems) must be corrected (4.2.1 and 4.2.2) so as to be representative of the total emissions from the affected facility. Conformance with this requirement may be accomplished in either of the following ways:

4.2.1 Installation of a diluent continuous monitoring system (O_2 or CO_2 as applicable) in accordance with the procedures under paragraph 4.2 of Performance Specification 3 of this appendix. If the pollutant and diluent monitoring systems are not of the same type (both extractive or both in-situ), the extractive system must use a multipoint probe.

4.2.2 Installation of extractive pollutant monitoring systems using multipoint sampling probes or in-situ pollutant monitoring systems that sample or view emissions which are consistently representative of the total emissions for the entire cross section. The Administrator may require data to be submitted to demonstrate that the emissions sampled or viewed are consistently representative for several typical facility process operating conditions.

4.3 The owner or operator may perform a traverse to characterize any stratification of effluent gases that might exist in a stack or duct. If no stratification is present, sampling procedures under paragraph 4.1 may be applied even though the eight diameter criteria is not met.

4.4 When single point sampling probes for extractive systems are installed within the stack or duct under paragraphs 4.1 and 4.2.1, the sample may not be extracted at any point less than 1.0 meter from the stack or duct wall. Multipoint sampling probes installed under paragraph 4.2.2 may be located at any points necessary to obtain consistently representative samples.

5. Continuous Monitoring System Performance Specifications.

The continuous monitoring system shall meet the performance specifications in Table 2-1 to be considered acceptable under this method.

TABLE 2-1.—*Performance specifications*

Parameter	*Specification*
1. Accuracy[1]	≤20 pct of the mean value of the reference method test data.
2. Calibration error[1]	≤5 pct of each (50 pct, 90 pct) calibration gas mixture value.
3. Zero drift (2 h)[1]	2 pct of span
4. Zero drift (24 h)[1]	Do.
5. Calibration drift (2 h)[1]	Do.
6. Calibration drift (24 h)[1]	2.5 pct. of span
7. Response time	15 min maximum.
8. Operational period	168 h minimum.

[1] Expressed as sum of absolute mean value plus 95 pct confidence interval of a series of tests.

6. Performance Specification Test Procedures. The following test procedures shall be used to determine conformance with the requirements of paragraph 5. For NO_x analyzers that oxidize nitric oxide (NO) to nitrogen dioxide (NO_2), the response time test under paragraph 6.3 of this method shall be performed using nitric oxide (NO) span gas. Other tests for NO_x continuous monitoring systems under paragraphs 6.1 and 6.2 and all tests for sulfur dioxide systems shall be performed using the pollutant span gas specified by each subpart.

6.1 Calibration Error Test Procedure. Set up and calibrate the complete continuous monitoring system according to the manufacturer's written instructions. This may be accomplished either in the laboratory or in the field.

6.1.1 Calibration Gas Analyses. Triplicate analyses of the gas mixtures shall be performed within two weeks prior to use using Reference Methods 6 for SO_2 and 7 for NO_x. Analyze each calibration gas mixture (50%, 90%) and record the results on the example sheet shown in Figure 2-1. Each sample test result must be within 20 percent of the averaged result or the tests shall be repeated. This step may be omitted for non-extractive monitors where dynamic calibration gas mixtures are not used (6.1.2).

6.1.2 Calibration Error Test Procedure. Make a total of 15 nonconsecutive measurements by alternately using zero gas and each calibration gas mixture/concentration (e.g., 0%, 50%, 0%, 90%, 50%, 90%, 50%, 0%, etc.). ~~For nonextractive continuous monitoring systems, this test procedure may be performed by using two or more calibration gas~~

cells whose concentrations are certified by the manufacturer to be functionally equivalent to these gas concentrations. Convert the continuous monitoring system output readings to ppm and record the results on the example sheet shown in *Figure* 2-2.

6.2 Field Test for Accuracy (Relative), Zero Drift, and Calibration Drift. Install and operate the continuous monitoring system in accordance with the manufacturer's written instructions and drawings as follows:

6.2.1 Conditioning Period. Offset the zero setting at least 10 percent of the span so that negative zero drift can be quantified. Operate the system for an initial 168-hour conditioning period in normal operating manner.

6.2.2 Operational Test Period. Operate the continuous monitoring system for an additional 168-hour period retaining the zero offset. The system shall monitor the source effluent at all times except when being zeroed, calibrated, or backpurged.

6.2.2.1 *Field Test for Accuracy (Relative).* For continuous monitoring systems employing extractive sampling, the probe tip for the continuous monitoring system and the probe tip for the Reference Method sampling train should be placed at adjacent locations in the duct. For NO_x continuous monitoring systems, make 27 NO_x concentration measurements, divided into nine sets, using the applicable reference method. No more than one set of tests, consisting of three individual measurements, shall be performed in any one hour. All individual measurements of each set shall be performed concurrently, or within a three-minute interval and the results averaged. For SO_2 continuous monitoring systems, make nine SO_2 concentration measurements using the applicable reference method. No more than one measurement shall be performed in any one hour. Record the reference method test data and the continuous monitoring system concentrations on the example data sheet shown in Figure 2-3.

6.2.2.2 Field Test for Zero Drift and Calibration Drift. For extractive systems, determine the values given by zero and span gas pollutant concentrations at two-hour intervals until 15 sets of data are obtained. For nonextractive measurement systems, the zero value may be determined by mechanically producing a zero condition that provides a system check of the analyzer internal mirrors and all electronic circuitry including the radiation source and detector assembly or by inserting three or more calibration gas cells and computing the zero point from the upscale measurements. If this latter technique is used, a graph(s) must be retained by the owner or operator for each measurement system that shows the relationship between the upscale measurements and the zero point. The span of the system shall be checked by using a calibration gas cell certified by the manufacturer to be functionally equivalent to 50 percent of span concentration. Record the zero and span measurements (or the computed zero drift) on the example data sheet shown in *Figure* 2-4. The two-hour periods over which measurements are conducted need not be consecutive but may not overlap. All measurements required under this paragraph may be conducted concurrent with tests under paragraph 6.2.2.1.

6.2.2.3 Adjustments. Zero and calibration corrections and adjustments are allowed only at 24-hour intervals or at such shorter intervals as the manufacturer's written instructions specify. Automatic corrections made by the measurement system without operator intervention or initiation are allowable at any time. During the entire 168-hour operational test period, record on the example sheet shown in *Figure* 2-5 the values given by zero and span gas pollutant concentrations before and after adjustment at 24-hour intervals.

6.3 Field Test for Response Time.

6.3.1 Scope of Test. Use the entire continuous monitoring system as installed, including sample transport lines if used. Flow rates, line diameters, pumping rates, pressures (do not allow the pressurized calibration gas to change the normal operating pressure in the sample line), etc., shall be at the nominal values for normal operation as specified in the manufacturer's written instructions. If the analyzer is used to sample more than one pollutant source (stack), repeat this test for each sampling point.

6.3.2 Response Time Test Procedure. Introduce zero gas into the continuous monitoring system sampling interface or as close to the sampling interface as possible. When the system output reading has stabilized, switch quickly to a known concentration of pollutant gas. Record the time from concentration switching to 95 percent of final stable response. For non-extractive monitors, the highest available calibration gas concentration shall be switched into and out of the sample path and response times recorded. Perform this test sequence three (3) times. Record the results of each test on the example sheet shown in *Figure* 2-6.

7. Calculations, Data Analysis and Reporting.

7.1 Procedure for determination of mean values and confidence intervals.

7.1.1 The mean value of a data set is calculated according to equation 2-1.

$$\bar{x}=\frac{1}{n}\sum_{i=1}^{n}x_i \qquad \text{Equation 2-1}$$

where:

x_i = absolute value of the measurements,

Σ = sum of the individual values,

$\bar{x}$ = mean value, and

n = number of data points.

7.1.2 The 95 percent confidence interval (two-sided) is calculated according to equation 2-2:

$$C.I._{95}=\frac{t_{.975}}{n\sqrt{n-1}}\sqrt{n(\Sigma x_i^2)-(\Sigma x_i)^2}$$

Equation 2-2

where:

$\sum x_i$ = sum of all data points,

$t_{.975} = t_1 - \alpha/2$, and

C.I.$_{95}$ = 95 percent confidence interval estimate of the average mean value.

Values for $t_{.975}$

n	$t_{.975}$
2	12.706
3	4.303
4	3.182
5	2.776
6	2.571
7	2.447
8	2.365
9	2.306
10	2.262
11	2.228
12	2.201
13	2.179
14	2.160
15	2.145
16	2.131

The values in this table are already corrected for n−1 degrees of freedom. Use n equal to the number of samples as data points.

7.2 Data Analysis and Reporting.

7.2.1 Accuracy (Relative). For each of the nine reference method test points, determine the average pollutant concentration reported by the continuous monitoring system. These average concentrations shall be determined from the continuous monitoring system data recorded under 7.2.2 by integrating or averaging the pollutant concentrations over each of the time intervals concurrent with each reference method testing period. Before proceeding to the next step, determine the basis (wet or dry) of the continuous monitoring system data and reference method test data concentrations. If the bases are not consistent, apply a moisture correction to either reference method concentrations or the continuous monitoring system concentrations as appropriate. Determine the correction factor by moisture tests concurrent with the reference method testing periods. Report the moisture test method and the correction procedure employed. For each of the nine test runs determine the difference for each test run by subtracting the respective reference method test concentrations (use average of each set of three measurements for NO_x) from the continuous monitoring system integrated or averaged concentrations. Using these data, compute the mean difference and the 95 percent confidence interval of the differences (equations 2-1 and 2-2). Accuracy is reported as the sum of the absolute value of the mean difference and the 95 percent confidence interval of the differences expressed as a percentage of the mean reference method value. Use the example sheet shown in Figure 2-3.

7.2.2 Calibration Error. Using the data from paragraph 6.1, subtract the measured pollutant concentration determined under paragraph 6.1.1 (Figure 2-1) from the value shown by the continuous monitoring system for each of the five readings at each concentration measured under 6.1.2 (Figure 2-2). Calculate the mean of these difference values and the 95 percent confidence intervals according to equations 2-1 and 2-2. Report the calibration error (the sum of the absolute value of the mean difference and the 95 percent confidence interval) as a percentage of each respective calibration gas concentration. Use example sheet shown in Figure 2-2.

7.2.3 Zero Drift (2-hour). Using the zero concentration values measured each two hours during the field test, calculate the differences between consecutive two-hour readings expressed in ppm. Calculate the mean difference and the confidence interval using equations 2-1 and 2-2. Report the zero drift as the sum of the absolute mean value and the confidence interval as a percentage of span. Use example sheet shown in Figure 2-4.

7.2.4 Zero Drift (24-hour). Using the zero concentration values measured every 24 hours during the field test, calculate the differences between the zero point after zero adjustment and the zero value 24 hours later just prior to zero adjustment. Calculate the mean value of these points and the confidence interval using equations 2-1 and 2-2. Report the zero drift (the sum of the absolute mean and confidence interval) as a percentage of span. Use example sheet shown in Figure 2-5.

7.2.5 Calibration Drift (2-hour). Using the calibration values obtained at two-hour intervals during the field test, calculate the differences between consecutive two-hour readings expressed as ppm. These values should be corrected for the corresponding zero drift during that two-hour period. Calculate the mean and confidence interval of these corrected difference values using equations 2-1 and 2-2. Do not use the differences between non-consecutive readings. Report the calibration drift as the sum of the absolute mean and confidence interval as a percentage of span. Use example sheet shown in Figure 2-4.

7.2.6 Calibration Drift (24-hour). Using the calibration values measured every 24 hours during the field test, calculate the differences between the calibration concentration reading after zero and calibration adjustment, and the calibration concentration reading 24 hours later after zero adjustment but before calibration adjustment. Calculate the mean value of these differences and the confidence interval using equations 2-1 and 2-2. Report the calibration drift (the sum of the absolute mean and confidence interval) as a percentage of span. Use the example sheet shown in Figure 2-5.

7.2.7 Response Time. Using the charts from paragraph 6.3, calculate the time interval from concentration switching to 95 percent to the final stable value for all upscale and downscale tests. Report the mean of the three upscale test times and the mean of the three downscale test times. The two average times should not differ by more than 15 percent of the slower time. Report the slower time as the system response time. Use the example sheet shown in Figure 2-6.

7.2.8 Operational Test Period. During the 168-hour performance and operational test period, the continuous monitoring system shall not require any corrective maintenance, repair, replacement, or adjustment other than that clearly specified as required in the operation and maintenance manuals as routine and expected during a one-week period. If the continuous monitoring system operates within the specified performance parameters and does not require corrective maintenance, repair, replacement or adjustment other than as specified above during the 168-hour test period, the operational period will be successfully concluded. Failure of the continuous monitoring system to meet this requirement shall call for a repetition of the 168-hour test period. Portions of the test which were satisfactorily completed need not be repeated. Failure to meet any performance specifications shall call for a repetition of the one-week performance test period and that portion of the testing which is related to the failed specification. All maintenance and adjustments required shall be recorded. Output readings shall be recorded before and after all adjustments.

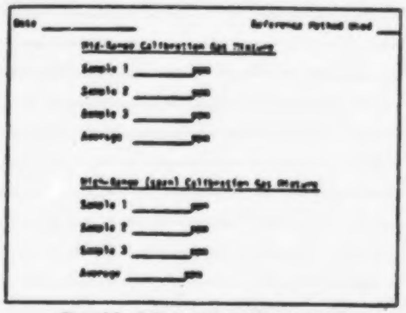
8. References.

8.1 "Monitoring Instrumentation for the Measurement of Sulfur Dioxide in Stationary Source Emissions," Environmental Protection Agency, Research Triangle Park, N.C., February 1973.

8.2 "Instrumentation for the Determination of Nitrogen Oxides Content of Stationary Source Emissions," Environmental Protection Agency, Research Triangle Park, N.C., Volume 1, APTD-0847, October 1971; Volume 2, APTD-0942, January 1972.

8.3 "Experimental Statistics," Department of Commerce, Handbook 91, 1963, pp. 3-31, paragraphs 3-3.1.4.

8.4 "Performance Specifications for Stationary-Source Monitoring Systems for Gases and Visible Emissions," Environmental Protection Agency, Research Triangle Park, N.C., EPA-650/2-74-013, January 1974.



Date ____________ Reference Method Used ____

Mid-Range Calibration Gas Mixture

Sample 1 ________ppm

Sample 2 ________ppm

Sample 3 ________ppm

Average ________ppm

High-Range (span) Calibration Gas Mixture

Sample 1 ________ppm

Sample 2 ________ppm

Sample 3 ________ppm

Average ________ppm

Figure 2-1. Analysis of Calibration Gas Mixtures

Monitor Performance Test Data Sheet

Calibration Gas Mixture Data (From Figure 2-1)

Mid (50%) _____ ppm   High (90%) _____ ppm

Run #	Calibration Gas Concentration, ppm	Measurement System Reading, ppm	Differences,[1] ppm
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

	Mid	High
Mean difference	_____	_____
Confidence interval	± _____	± _____
Calibration error = $\frac{\text{Mean Difference}^2 + \text{C.I.}}{\text{Average Calibration Gas Concentration}} \times 100$	_____ %	_____ %

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[1] Calibration gas concentration - measurement system reading

[2] Absolute value

Figure 2-2. Calibration Error Determination

Test No.	Date and Time	Reference Method Samples					Analyzer 1-Hour Average (ppm)*		Difference (ppm)	
		SO_2 Sample 1 (ppm)	NO Sample 1 (ppm)	NO Sample 2 (ppm)	NO Sample 3 (ppm)	NO Sample Average (ppm)	SO_2	NO_x	SO_2	NO_x
1										
2										
3										
4										
5										
6										
7										
8										
9										
Mean reference method test value (SO_2) ______			Mean reference method test value (NO_x) ______				Mean of the differences ______			

95% Confidence intervals = ± ______ ppm (SO_2) = ± ______ ppm (NO_x)

Accuracies = $\frac{|\text{Mean of the differences}| + 95\%\ \text{confidence interval}}{\text{Mean reference method value}}$ × 100 = ___% (SO_2) = ___% (NO_x)

* Explain and report method used to determine integrated averages

Figure 2-3. Accuracy Determination (SO_2 and NO_x)

Data Set No.	Time Begin	Time End	Date	Zero Reading	Zero Drift (ΔZero)	Span Reading	Span Drift (ΔSpan)	Calibration Drift (Span- Zero)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

Zero Drift = [Mean Zero Drift* ______ + CI (Zero) ______] ÷ [Span] × 100 = ______.
Calibration Drift = [Mean Span Drift* ______ + CI (Span) ______] ÷ [Span] × 100 = ______.
*Absolute Value.

Figure 2-4. Zero and Calibration Drift (2 Hour)

Date and Time	Zero Reading	Zero Drift (ΔZero)	Span Reading (After zero adjustment)	Calibration Drift (ΔSpan)

Zero Drift = [Mean Zero Drift* _______ + C.I. (Zero) _______]

÷ [Instrument Span] x 100 = _________.

Calibration Drift = [Mean Span Drift* _________ + C.I. (Span) _________]

÷ [Instrument Span] x 100 = _________.

* Absolute value

Figure 2-5. Zero and Calibration Drift (24-hour)

Date of Test ____________

Span Gas Concentration ________ ppm

Analyzer Span Setting ________ ppm

Upscale
1 ________ seconds
2 ________ seconds
3 ________ seconds

Average upscale response ________ seconds

Downscale
1 ________ seconds
2 ________ seconds
3 ________ seconds

Average downscale response ______ seconds

System average response time (slower time) = _______ seconds.

$$\%\text{deviation from slower system average response} = \left[\frac{\text{average upscale minus average downscale}}{\text{slower time}}\right] \times 100\% = \_\_\_\_.$$

CO_2 & O_2

Figure 2-6. Response Time

Performance Specification 3—Performance specifications and specification test procedures for monitors of CO_2 and O_2 from stationary sources.

1. Principle and Applicability.

1.1 Principle. Effluent gases are continuously sampled and are analyzed for carbon dioxide or oxygen by a continuous monitoring system. Tests of the system are performed during a minimum operating period to determine zero drift, calibration drift, and response time characteristics.

1.2 Applicability. This performance specification is applicable to evaluation of continuous monitoring systems for measurement of carbon dioxide or oxygen. These specifications contain test procedures, installation requirements, and data computation procedures for evaluating the acceptability of the continuous monitoring systems subject to approval by the Administrator. Sampling may include either extractive or non-extractive (in-situ) procedures.

2. Apparatus.

2.1 Continuous Monitoring System for Carbon Dioxide or Oxygen.

2.2 Calibration Gas Mixtures. Mixture of known concentrations of carbon dioxide or oxygen in nitrogen or air. Midrange and 90 percent of span carbon dioxide or oxygen concentrations are required. The 90 percent of span gas mixture is to be used to set and check the analyzer span and is referred to as span gas. For oxygen analyzers, if the span is higher than 21 percent O_2, ambient air may be used in place of the 90 percent of span calibration gas mixture. Triplicate analyses of the gas mixture (except ambient air) shall be performed within two weeks prior to use using Reference Method 3 of this part.

2.3 Zero Gas. A gas containing less than 100 ppm of carbon dioxide or oxygen.

2.4 Data Recorder. Analog chart recorder or other suitable device with input voltage range compatible with analyzer system output. The resolution of the recorder's data output shall be sufficient to allow completion of the test procedures within this specification.

3. Definitions.

3.1 Continuous Monitoring System. The total equipment required for the determination of carbon dioxide or oxygen in a given source effluent. The system consists of three major subsystems:

3.1.1 Sampling Interface. That portion of the continuous monitoring system that performs one or more of the following operations: Delineation, acquisition, transportation, and conditioning of a sample of the source effluent or protection of the analyzer from the hostile aspects of the sample or source environment.

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3.1.2 Analyzer. That portion of the continuous monitoring system which senses the pollutant gas and generates a signal output that is a function of the pollutant concentration.

3.1.3 Data Recorder. That portion of the continuous monitoring system that provides a permanent record of the output signal in terms of concentration units.

3.2 Span. The value of oxygen or carbon dioxide concentration at which the continuous monitoring system is set that produces the maximum data display output. For the purposes of this method, the span shall be set no less than 1.5 to 2.5 times the normal carbon dioxide or normal oxygen concentration in the stack gas of the affected facility.

3.3 Midrange. The value of oxygen or carbon dioxide concentration that is representative of the normal conditions in the stack gas of the affected facility at typical operating rates.

3.4 Zero Drift. The change in the continuous monitoring system output over a stated period of time of normal continuous operation when the carbon dioxide or oxygen concentration at the time for the measurements is zero.

3.5 Calibration Drift. The change in the continuous monitoring system output over a stated time period of normal continuous operation when the carbon dioxide or oxygen continuous monitoring system is measuring the concentration of span gas.

3.6 Operational Test Period. A minimum period of time over which the continuous monitoring system is expected to operate within certain performance specifications without unscheduled maintenance, repair, or adjustment.

3.7 Response time. The time interval from a step change in concentration at the input to the continuous monitoring system to the time at which 95 percent of the corresponding final value is displayed on the continuous monitoring system data recorder.

4. Installation Specification.

Oxygen or carbon dioxide continuous monitoring systems shall be installed at a location where measurements are directly representative of the total effluent from the affected facility or representative of the same effluent sampled by a SO_2 or NO_x continuous monitoring system. This requirement shall be complied with by use of applicable requirements in Performance Specification 2 of this appendix as follows:

4.1 Installation of Oxygen or Carbon Dioxide Continuous Monitoring Systems Not Used to Convert Pollutant Data. A sampling location shall be selected in accordance with the procedures under paragraphs 4.2.1 or 4.2.2, or Performance Specification 2 of this appendix.

4.2 Installation of Oxygen or Carbon Dioxide Continuous Monitoring Systems Used to Convert Pollutant Continuous Monitoring System Data to Units of Applicable Standards. The diluent continuous monitoring system (oxygen or carbon dioxide) shall be installed at a sampling location where measurements that can be made are representative of the effluent gases sampled by the pollutant continuous monitoring system(s). Conformance with this requirement may be accomplished in any of the following ways:

4.2.1 The sampling location for the diluent system shall be near the sampling location for the pollutant continuous monitoring system such that the same approximate point(s) (extractive systems) or path (in-situ systems) in the cross section is sampled or viewed.

4.2.2 The diluent and pollutant continuous monitoring systems may be installed at different locations if the effluent gases at both sampling locations are nonstratified as determined under paragraphs 4.1 or 4.2, Performance Specification 2 of this appendix and there is no in-leakage occurring between the two sampling locations. If the effluent gases are stratified at either location, the procedures under paragraph 4.2.2, Performance Specification 2 of this appendix shall be used for installing continuous monitoring systems at that location.

5. Continuous Monitoring System Performance Specifications.

The continuous monitoring system shall meet the performance specifications in Table 3–1 to be considered acceptable under this method.

6. Performance Specification Test Procedures.

The following test procedures shall be used to determine conformance with the requirements of paragraph 4. Due to the wide variation existing in analyzer designs and principles of operation, these procedures are not applicable to all analyzers. Where this occurs, alternative procedures, subject to the approval of the Administrator, may be employed. Any such alternative procedures must fulfill the same purposes (verify response, drift, and accuracy) as the following procedures, and must clearly demonstrate conformance with specifications in Table 3–1.

6.1 Calibration Check. Establish a calibration curve for the continuous monitoring system using zero, midrange, and span concentration gas mixtures. Verify that the resultant curve of analyzer reading compared with the calibration gas value is consistent with the expected response curve as described by the analyzer manufacturer. If the expected response curve is not produced, additional calibration gas measurements shall be made, or additional steps undertaken to verify the accuracy of the response curve of the analyzer.

6.2 Field Test for Zero Drift and Calibration Drift. Install and operate the continuous monitoring system in accordance with the manufacturer's written instructions and drawings as follows:

TABLE 3-1.—*Performance specifications*

Parameter	*Specification*
1. Zero drift (2 h) [1]	≤0.4 pct O_2 or CO_2.
2. Zero drift (24 h) [1]	≤0.5 pct O_2 or CO_2.
3. Calibration drift (2 h) [1]	≤0.4 pct O_2 or CO_2.
4. Calibration drift (24 h) [1]	≤0.5 pct O_2 or CO_2.
5. Operational period	168 h minimum.
6. Response time	10 min.

[1] Expressed as sum of absolute mean value plus 95 pct confidence interval of a series of tests.

6.2.1 Conditioning Period. Offset the zero setting at least 10 percent of span so that negative zero drift may be quantified. Operate the continuous monitoring system for an initial 168-hour conditioning period in a normal operational manner.

6.2.2. Operational Test Period. Operate the continuous monitoring system for an additional 168-hour period maintaining the zero offset. The system shall monitor the source effluent at all times except when being zeroed, calibrated, or backpurged.

6.2.3 Field Test for Zero Drift and Calibration Drift. Determine the values given by zero and midrange gas concentrations at two-hour intervals until 15 sets of data are obtained. For non-extractive continuous monitoring systems, determine the zero value given by a mechanically produced zero condition or by computing the zero value from upscale measurements using calibrated gas cells certified by the manufacturer. The midrange checks shall be performed by using certified calibration gas cells functionally equivalent to less than 50 percent of span. Record these readings on the example sheet shown in Figure 3-1. These two-hour periods need not be consecutive but may not overlap. In-situ CO_2 or O_2 analyzers which cannot be fitted with a calibration gas cell may be calibrated by alternative procedures acceptable to the Administrator. Zero and calibration corrections and adjustments are allowed only at 24-hour intervals or at such shorter intervals as the manufacturer's written instructions specify. Automatic corrections made by the continuous monitoring system without operator intervention or initiation are allowable at any time. During the entire 168-hour test period, record the values given by zero and span gas concentrations before and after adjustment at 24-hour intervals in the example sheet shown in Figure 3-2.

6.3 Field Test for Response Time.

6.3.1 Scope of Test.

This test shall be accomplished using the continuous monitoring system as installed, including sample transport lines if used. Flow rates, line diameters, pumping rates, pressures (do not allow the pressurized calibration gas to change the normal operating pressure in the sample line), etc., shall be at the nominal values for normal operation as specified in the manufacturer's written instructions. If the analyzer is used to sample more than one source (stack), this test shall be repeated for each sampling point.

6.3.2 Response Time Test Procedure.

Introduce zero gas into the continuous monitoring system sampling interface or as close to the sampling interface as possible. When the system output reading has stabilized, switch quickly to a known concentration of gas at 90 percent of span. Record the time from concentration switching to 95 percent of final stable response. After the system response has stabilized at the upper level, switch quickly to a zero gas. Record the time from concentration switching to 95 percent of final stable response. Alternatively, for nonextractive continuous monitoring systems, the highest available calibration gas concentration shall be switched into and out of the sample path and response times recorded. Perform this test sequence three (3) times. For each test, record the results on the data sheet shown in Figure 3-3.

7. Calculations, Data Analysis, and Reporting.

7.1 Procedure for determination of mean values and confidence intervals.

7.1.1 The mean value of a data set is calculated according to equation 3-1.

$$\bar{x}=\frac{1}{n}\sum_{i=1}^{n}x_i \qquad \text{Equation 3-1}$$

where:

x_i=absolute value of the measurements,
Σ=sum of the individual values,
$\bar{x}$=mean value, and
n=number of data points.

7.2.1 The 95 percent confidence interval (two-sided) is calculated according to equation 3-2:

$$C.I._{95}=\frac{t_{.975}}{n\sqrt{n-1}}\sqrt{n(\sum x_i^2)-(\sum x_i)^2} \qquad \text{Equation 3-2}$$

where:

ΣX=sum of all data points,
$t_{.975}=t_{1-\alpha/2}$, and
$C.I._{95}$=95 percent confidence interval estimates of the average mean value.

Values for $t_{.975}$

n	$t_{.975}$
2	12.706
3	4.303
4	3.182
5	2.776
6	2.571
7	2.447
8	2.365
9	2.306
10	2.262
11	2.228
12	2.201
13	2.179
14	2.160
15	2.145
16	2.131

The values in this table are already corrected for n-1 degrees of freedom. Use n equal to the number of samples as data points.

7.2 Data Analysis and Reporting.

7.2.1 Zero Drift (2-hour). Using the zero concentration values measured each two hours during the field test, calculate the differences between the consecutive two-hour readings expressed in ppm. Calculate the mean difference and the confidence interval using equations 3-1 and 3-2. Record the sum of the absolute mean value and the confidence interval on the data sheet shown in Figure 3-1.

7.2.2 Zero Drift (24-hour). Using the zero concentration values measured every 24 hours during the field test, calculate the differences between the zero point after zero adjustment and the zero value 24 hours later just prior to zero adjustment. Calculate the mean value of these points and the confidence interval using equations 3-1 and 3-2. Record the zero drift (the sum of the absolute mean and confidence interval) on the data sheet shown in Figure 3-2.

7.2.3 Calibration Drift (2-hour). Using the calibration values obtained at two-hour intervals during the field test, calculate the differences between consecutive two-hour readings expressed as ppm. These values should be corrected for the corresponding zero drift during that two-hour period. Calculate the mean and confidence interval of these corrected difference values using equations 3-1 and 3-2. Do not use the differences between non-consecutive readings. Record the sum of the absolute mean and confidence interval upon the data sheet shown in Figure 3-1.

7.2.4 Calibration Drift (24-hour). Using the calibration values measured every 24 hours during the field test, calculate the differences between the calibration concentration reading after zero and calibration adjustment and the calibration concentration reading 24 hours later after zero adjustment but before calibration adjustment. Calculate the mean value of these differences and the confidence interval using equations 3-1 and 3-2. Record the sum of the absolute mean and confidence interval on the data sheet shown in Figure 3-2.

7.2.5 Operational Test Period. During the 168-hour performance and operational test period, the continuous monitoring system shall not receive any corrective maintenance, repair, replacement, or adjustment other than that clearly specified as required in the manufacturer's written operation and maintenance manuals as routine and expected during a one-week period. If the continuous monitoring system operates within the specified performance parameters and does not require corrective maintenance, repair, replacement or adjustment other than as specified above during the 168-hour test period, the operational period will be successfully concluded. Failure of the continuous monitoring system to meet this requirement shall call for a repetition of the 168 hour test period. Portions of the test which were satisfactorily completed need not be repeated. Failure to meet any performance specifications shall call for a repetition of the one-week performance test period and that portion of the testing which is related to the failed specification. All maintenance and adjustments required shall be recorded. Output readings shall be recorded before and after all adjustments.

7.2.6 Response Time. Using the data developed under paragraph 6.3, calculate the time interval from concentration switching to 95 percent to the final stable value for all upscale and downscale tests. Report the mean of the three upscale test times and the mean of the three downscale test times. The two average times should not differ by more than 15 percent of the slower time. Report the slower time as the system response time. Record the results on Figure 3-3.

8. References.

8.1 "Performance Specifications for Stationary Source Monitoring Systems for Gases and Visible Emissions," Environmental Protection Agency, Research Triangle Park, N.C., EPA-650/2-74-013, January 1974.

8.2 "Experimental Statistics," Department of Commerce, National Bureau of Standards Handbook 91, 1963, pp. 3-31, paragraphs 3-3.1.4.

Data Set No.	Time		Date	Zero Reading	Zero Drift (ΔZero)	Span Reading	Span Drift (ΔSpan)	Calibration Drift [ΔSpan-ΔZero)
	Begin	End						
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

Zero Drift = [Mean Zero Drift* ________ + CI (Zero) ________] = ________.
Calibration Drift = [Mean Span Drift* ______ + CI (Span ______] = ________.
*Absolute Value.

Figure 3-1. Zero and Calibration Drift (2 Hour).

Date and Time	Zero Reading	Zero Drift (ΔZero)	Span Reading (After zero adjustment)	Calibration Drift (ΔSpan)

Zero Drift = [Mean Zero Drift* ______ + C.I. (Zero) ______]

= ______.

Calibration Drift = [Mean Span Drift* ______ + C.I. (Span) ______]

= ______.

* Absolute value

Figure 3-2. Zero and Calibration Drift (24-hour)

Date of Test ____________

Span Gas Concentration ________ ppm

Analyzer Span Setting ________ ppm

Upscale
1. ________ seconds
2. ________ seconds
3. ________ seconds

Average upscale response ________ seconds

Downscale
1. ________ seconds
2. ________ seconds
3. ________ seconds

Average downscale response ________ seconds

System average response time (slower time) = ________ seconds

% deviation from slower system average response = $\frac{\text{average upscale minus average downscale}}{\text{slower time}}$ x 100%

= ________.

Figure 3-3. Response

[40 FR 46250, Oct. 6, 1975; 40 FR 59204, 59205, Dec. 22, 1975, as amended at 42 FR 5937, Jan. 31, 1977]

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APPENDIX C—DETERMINATION OF EMISSION RATE CHANGE

1. *Introduction.*

1.1 The following method shall be used to determine whether a physical or operational change to an existing facility resulted in an increase in the emission rate to the atmosphere. The method used is the Student's *t* test, commonly used to make inferences from small samples.

2. *Data.*

2.1 Each emission test shall consist of *n* runs (usually three) which produce *n* emission rates. Thus two sets of emission rates are generated, one before and one after the change, the two sets being of equal size.

2.2 When using manual emission tests, except as provided in § 60.8(b) of this part, the reference methods of Appendix A to this part shall be used in accordance with the procedures specified in the applicable subpart both before and after the change to obtain the data.

2.3 When using continuous monitors, the facility shall be operated as if a manual emission test were being performed. Valid data using the averaging time which would be required if a manual emission test were being conducted shall be used.

3. *Procedure.*

3.1 Subscripts a and b denote prechange and postchange respectively.

3.2 Calculate the arithmetic mean emission rate, $\bar{E}$, for each set of data using Equation 1.

$$\bar{E}=\frac{\sum_{i=1}^{n} E_i}{n}=\frac{E_1+E_2\ldots+E_n}{n} \qquad (1)$$

where:

E_i = Emission rate for the *i* th run.
n = number of runs

3.3 Calculate the sample variance, S^2, for each set of data using Equation 2.

$$S^2=\frac{\sum_{i=1}^{n}(E_i-\bar{E})^2}{n-1}=\frac{\sum_{i=1}^{n}E_i^2-\left(\sum_{i=1}^{n}E_i\right)^2\Big/n}{n-1} \qquad (2)$$

3.4 Calculate the pooled estimate, S_p, using Equation 3.

$$S_p=\left[\frac{(n_a-1)\,S_a^2+(n_b-1)\,S_b^2}{n_a+n_b-2}\right]^{1/2} \qquad (3)$$

3.5 Calculate the test statistic, *t*, using Equation 4.

APPENDIX E

RESULTS OF PREVIOUS TESTS AT SITE 4

Sampling Locations

Unit #3 is equipped with a Western Precipitator Multiclone cyclone type dust collector. Sampling sites were selected such that inlet and outlet data and emission characteristics were obtained for the collection device. The inlet sampling plane, located just upstream of the cycone in the inlet breaching, was the only area available to obtain inlet data due to the duct configuration of the boiler. Figure E-1 presents a cross sectional diagram of the inlet sampling site. This site was somewhat unsuitable for particulate measurements due to its nearness to an upstream bend in the ducting. Some of the inlet particulate data is questionable, however the gaseous data is accurate. Figure E-2 presents the cross sectional view of the inlet sampling probe locations. Twelve probes were installed for gaseous emission testing and of these twelve stainless steel probes, six were equipped to measure hot line data. The twelve probes were installed in six ports, two in each port. Twelve 3/8 inch diameter type-T nylon sample lines connected the sample probes to the mobile test lab. Sampling took place during the middle of winter in the cold prairie section of the Midwest. The sections of sample lines that were outside the building were insulated with fiberglass insulation and wrapped with a pipe heating tape. The entire sample line bundle was covered with a waterproof plastic liner to protect it from moisture.

An existing location in a section of breeching between the ID fan and chimney was used for the outlet sample site (Fig. E-2). This location had been used for previous compliance tests. Four ports were located at the site. Three probes were installed into each port at the centroids of equal areas for a total of twelve sample probes. This sample site was outside and special insulating material and heating tapes were required to keep the nylon sample lines from freezing during the cold winter weather.

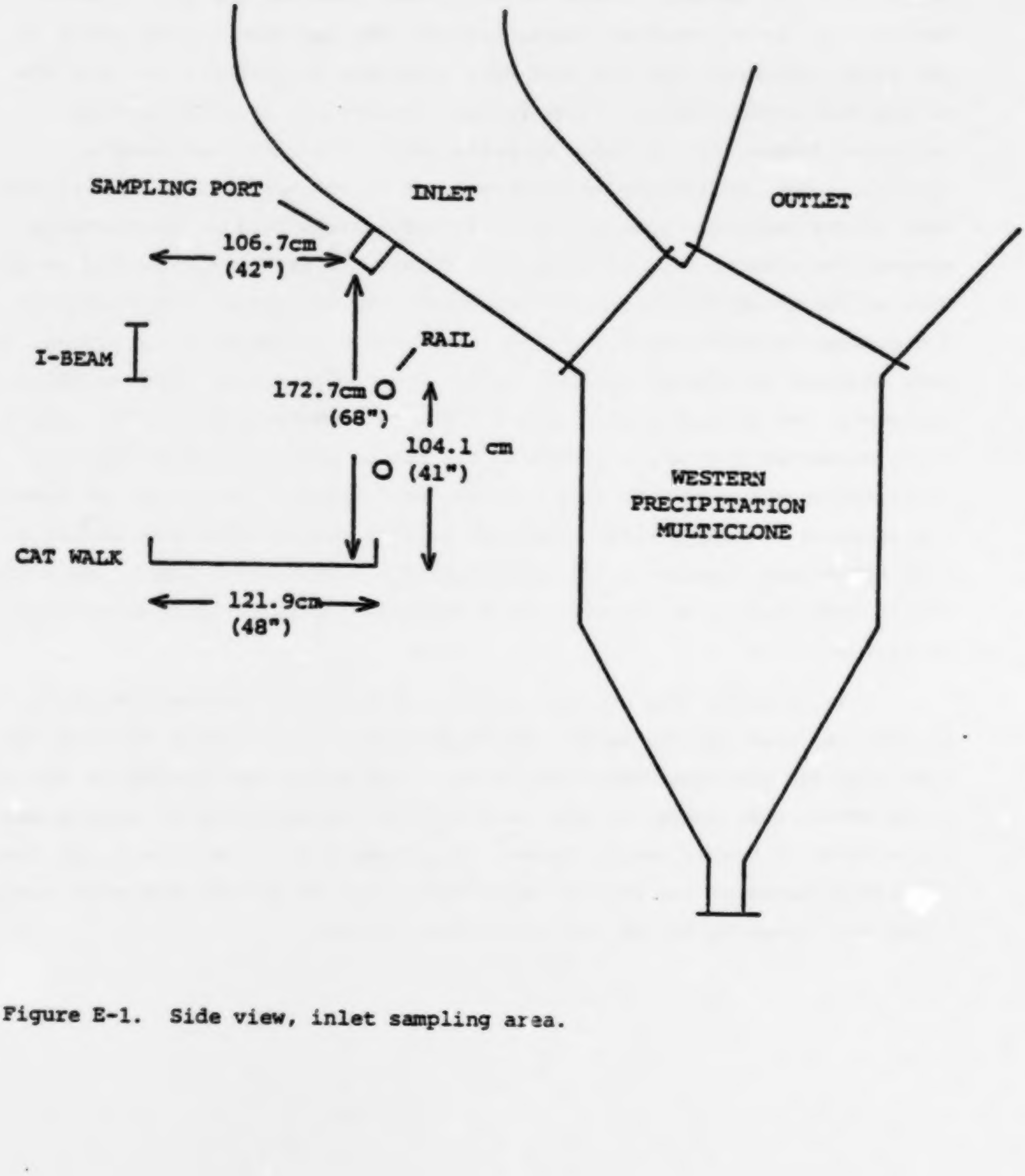

Figure E-1. Side view, inlet sampling area.

Cross Sectional Area: $6.039\ m^2$ ($65.0\ ft^2$)

Probe Lengths from Outside Edge of Port: 43.34 cm (17-3/4"),
93.98 cm (37-1/4")

Probe Numbers Shown
Probe Numbers 1, 4, 5, 8, 9, 12 equipped for Hot Line Testing

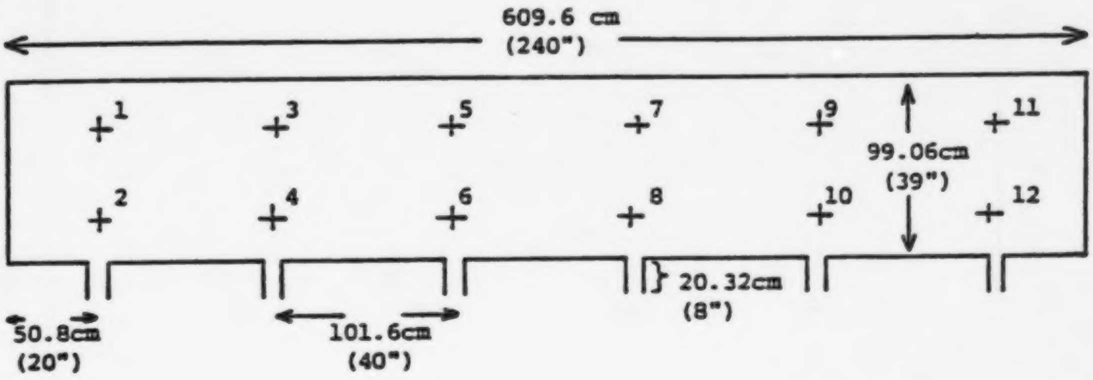

Figure E-2. Cross section, inlet sampling duct, top view, gas flow is into paper.

Cross Sectional Area: 2.016 m^2 (21.7 ft^2)

Probe Lengths From Outside Edge of Port: 35.56 cm (14-1/8"), 76.2 cm (30-3/8"), 16.8 cm (46-5/8")

Probe Numbers Shown

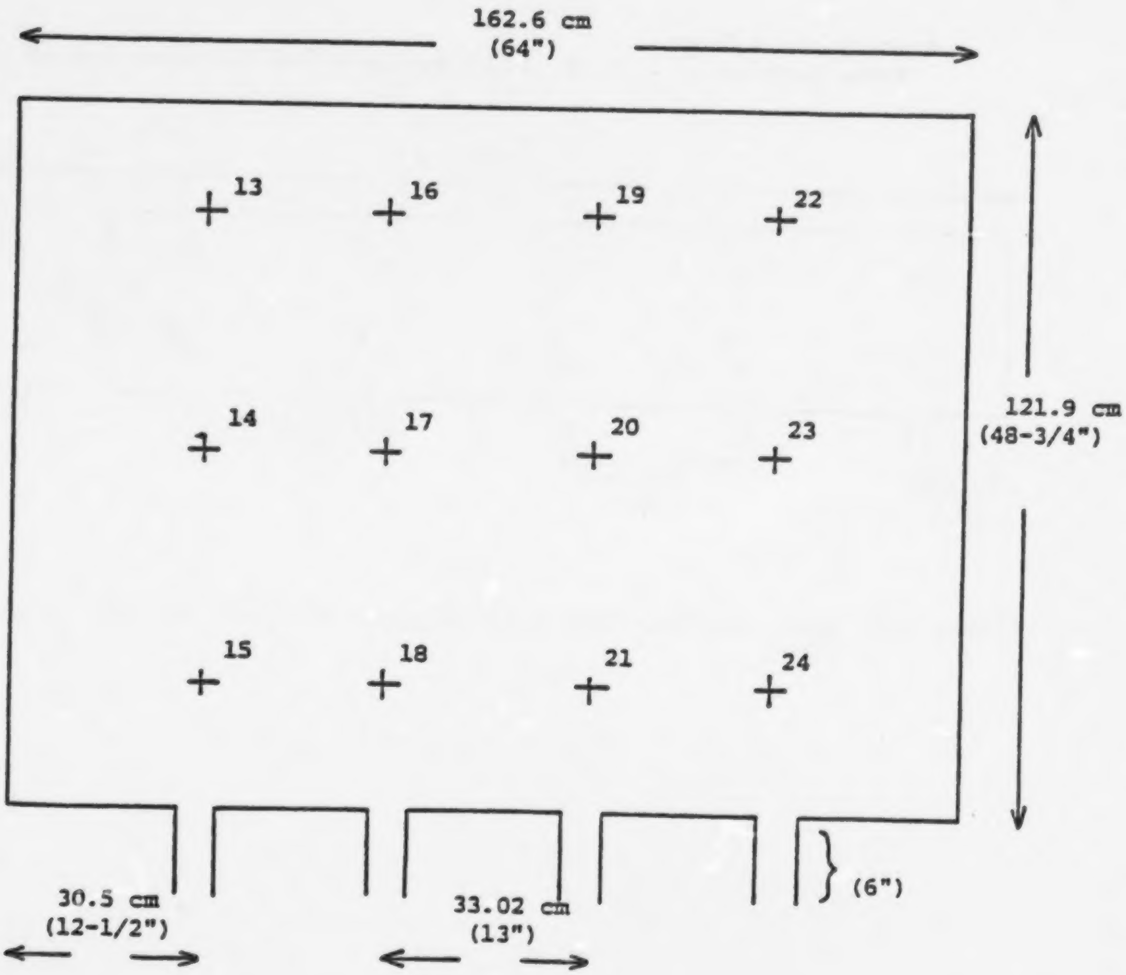

Figure E-3. Cross section, outlet sampling duct, top view, gas flow is out of paper.

Comparison of Test Coals

Unit #3 normally burns a western type fuel, because the utility had trouble in obtaining a reliable supply of eastern coals. Several years ago they switched to the more dependable western coal supplier. The western coal burned during these tests was a Montana coal from Colstrip, Montana. For the test series a special order of eastern type coal was obtained. This fuel was from the Sahara mine in Southern Illinois. As with most western subbituminous coals the Colstrip coal had a high moisture content, high volatile and low fixed carbon content and moderate sulfur content.

Western Coal Burning at Unit #3

Montana coal is normally burned at this facility. A small penalty is paid in total unit capacity when using the subbituminous coal in a stoker originally designed to fire a high Btu eastern type coal. The maximum load obtained with the Montana coal was 16.1 kg/s (128,000 lb/hr) steam flow while the maximum load on the Southern Illinois fuel was 16.8 kg/s (133,400 lb/hr) steam flow. These values are somewhat deceptive since, at the time the boiler was tested, there was a defective air heater in service. This air heater had large leaks in it which allowed incoming air to short circuit its route to the combustion zone, and hence starve the undergrate air chamber. This resulted in the unit smoking at a lower than normal maximum load on the eastern coal and resulting in a reduced maximum load at the given conditions. The unit should be able to make 20.2 kg/s (160,000 lb/hr) steam flow with the eastern coal when the air heater is repaired and the stoker is properly adjusted.

Western coal can be successfully fired on a spreader stoker with only minor changes in existing equipment. For a given boiler output, feeder rates must be increased to get the same amount of energy input into the stoker on western coal as for eastern coal. The fineness of the western coal ash requires thicker bed to prevent ash from being blown off the grate. Unit #3 ran an ash bed thickness of 5 to 10 cm when firing western fuel. Feeder rates were increased about 10 to 15 percent.

Higher superheat temperatures were encountered with the higher moisture western coals. Unit #3 was equipped with a through-th-mud drum type steam attemperator. This device was used when firing western coal to control the superheat temperature. No control read-outs were available to measure the absolute percentage of steam by-passed into the attemperator but the controller which controlled the bypass valve was set at about 50 percent for Montana coal. Increasing the overfire air can reduce the CO emissions somewhat; but, the unit did not operate in that mode as a normal operating procedure. A short series of tests ran overfire air pressure from normal as-found settings of 7.5 - 8.5 inches H_2O to the maximum setting, and corresponding CO emissions of 181 ppm at 3.0% excess O_2 were reduced to 140 ppm at 3.0% excess O_2. Nitric oxide emissions did not vary significantly with the change in overfire air.

There was no appreciable flame impingement on the furnace side walls or back walls with western coal firing. The fuel bed was uniform and well established. The coal combustion on the grate was nonswelling and nonagglomerating. Coke pieces tended to retain their individual size and identity when burning on the grate. The main flame front began about four feet from the vertical plane of the feeders for western coal burning. No clinkers were formed while burning western coal. There were "sparklers" or suspension burning with the western coal. These sparklers were carried up into the superheat pendant section.

Moderate slagging occurred in the superheat pendant tube section. Slag deposits of two to four inches in thickness covered the pendant loops about 1/2 to 2/3 up the tubes. There was some flame impingement on these areas. Some slag build-up was sufficient to cause bridging of formations between pendants, however it was not of sufficient quantity as to cause flow restriction through the superheater.

Generally the Montana coal performed well on the stoker. Except for the reduced load, the coal was a better fuel than the eastern coal which clinkered and had a serious smoking problem.

Emissions Data

A. Sulfur Oxides--

Table E-1 contains a summary of all emission tests conducted at this unit on both eastern and western coal. In all, thirty-four tests were run (fourteen on eastern coal and twenty on western coal). Sulfur oxides emissions from western coal were about half that of eastern coal. The average SO_2 emissions from the eastern coal were 1489 ng/J (3.47 lb/10^6 Btu) compared to 766 ng/J (1.79 lb/10^6 Btu). The Colstrip coal tested on this unit exhibited the greatest sulfur retention of any coal tested with an average of only 65% of the fuel sulfur emitted in the flue gas. This number compares to a fuel sulfur emissions of 94% on eastern coal on this same unit.

The SO_2 emissions from either the western or the eastern coal did not follow a trend with either load or excess air. The SO_3 component of the SOx emission was generally less than 3 percent of the total. Neither the amount of SO_3 nor the ratio of SO_3/SOx exhibited a definable trend with any of the test variables.

B. Particulates--

The uncontrolled particulate loadings were found to exceed the ash content of the fuel by as much as a factor of four. Even when the carbon content of the ash was taken into account, these figures could not be reconciled with the uncontrolled particulate loadings. Therefore, the error must be with the sampling location described above.

Controlled particulate loading were within reasonable limits of 166-545 ng/J (0.39 - 1.27 lb/10^6 Btu). The overall average particulate loading of all the tests for eastern and western coal are shown in Table E-1. The average western coal emission was some 24% less than the average for eastern coal. The carbon content of the western coal fly ash was also 33% less than that from the eastern coal. The particulate emissions followed no definable

TABLE E-1. EMISSION SUMMARY, UNIT 3

Test No.	Date	Load kg/s (10^3 lb/hr)	Conditions	SO_2 Meter 3% O_2 ppm	CYCLONE INLET				CYCLONE OUTLET						Part ng/J (#/MBtu) Out	SOx ppm	Notes
					O_2, %	CO ppm 3% O_2	CO_2 %	NO ppm 3% O_2	O_2, %	CO ppm 3% O_2	CO_2 %	NO ppm 3% O_2	kg Steam / kg Coal	% C in Ash			
EASTERN COAL																	
21	1/15/75	13.5 (107.4)	Normal O_2, Med. Load	OOS	8.59	314	9.15	447	9.0	108	8.8	495	8.2	--	--	1643	Prelim. Unit Check Out
22	1/19	14.1 (112.0)	Normal O_2, Med. Load	OOS	8.22	369	9.74	471	8.65	351	9.4	445	8.6	--	--	1534	
23	1/20	22.8 (114.5)	Normal O_2, Med. Load	OOS	8.17	146	9.9	491	9.13	367	8.9	439	8.7	26.8	316 (0.7355)	--	Part In and Out
24	1/21	14.1 (111.7)	Normal O_2, Med. Load	OOS	8.38	368	9.67	514	8.6	1306	8.8	515	8.6	--	--	1462 1589	SOx In SOx Out
25	1/22	13.3 (105.4)	High O_2, Med. Load Spill Plate Reset	1798	9.43	44	9.03	491	11.0	20	8.4	502	8.6	25.8	371 (0.8622)	--	Part In and Out
26	1/23	13.3 (105.5)	High O_2, Med. Load In Out	1795 1712	8.56	39	9.16	532	8.7	44	8.8	520	8.7	--	--	2067	SOx Inlet
27	1/26	15.6 (124.0)	Normal O_2, High Load	OOS	6.62	289	11.13	415		FROZE			8.4	--	--	1849	SOx Inlet
28	1/27	15.8 (125.4)	Normal O_2, High Load	OOS	6.45	509	11.24	395	7.4	520	10.6	293	8.3	26.9	294 (0.6834)	1721	SOx Inlet
29	1/28	11.4 (91.0)	Normal O_2, Low-Med. Load	OOS	7.42	113	10.54	366		FROZE			8.9	--	--	--	Gaseous Only
30	1/30	10.5 (83.5)	Normal O_2, Low Load	OOS	9.95	51	8.55	441	10.7	58	7.88	432	8.5	25.9	350 (0.8135)	1651	Part In and Out; SOx In
31	1/31	9.6 (76.1)	Low O_2, Low Load	OOS	8.38	26	9.91	341		FROZE		--	8.1	28.4	264 (0.6131)	1788	Part In and Out; SOx In
32	2/1	11.0 (87.3)	High O_2, Low Load	OOS	11.92	84	7.38	492	12.3	90	7.4	481	8.5	26.8	545 (1.2670)	1792	Part In and Out; SOx In
33	2/2	13.8 (109.8)	Low O_2, Med. Load	OOS	6.63	89	11.08	375	--	--	--	--	8.7	28.0	234 (0.5443)	1778	Part In and Out; SOx In
34	2/5	16.8 (133.4)	Max. Cont. Load, Post D.S. Boiler Tune Up	--	5.85	216	11.7	336	7.2	205	10.9	326	8.67	28.0	320 (0.7650)	1815	Part In and Out; SOx In
Average		13.4 (106.2)			8.18	190	9.87	436	9.27	315	8.99	445	8.53	27	338 (0.7855)	1724	

(continued)

TABLE E-1. (continued)

Test No.	Date	Load kg/s (10^3 lb/hr)	Conditions	SO_2 Meter 3% O_2 ppm	CYCLONE INLET				CYCLONE OUTLET						Part ng/J (#/MBtu) Out	SOx ppm	Notes
					O_2, %	CO ppm 3% O_2	CO_2 %	NO ppm 3% O_2	O_2, %	CO ppm 3% O_2	CO_2 %	NO ppm 3% O_2	kg Steam / kg Coal	% C in Ash			
WESTERN COAL																	
1	12/2/75	13.5 (107)	Normal O_2, Normal Operation	972	7.8	540	10.3	363	--	--	--	--	5.85	--	--	867	SOx Out
2	12/3	14.1 (112)	Normal O_2, Normal Operation	827	7.3	880	10.4	387	--	--	--	--	5.80	--	--	785	SOx In
3	12/4	12.3 (97.5)	Normal O_2, Normal Operation	793	7.9	527	10.1	389	--	--	--	--	5.81	19.1	$\frac{10,956}{325}$ $\left(\frac{25.40}{0.7551}\right)$	--	Part In Part Out
4	12/5	13.0 (103)	Normal O_2, Normal Operation	776	7.6	800	10.4	398	8.6	466	10.1	407	5.86	--	--	851	Meter Outlet
5A	12/8	13.2 (105)	Vary Overfire Air (OFA) As Found	1126	9.2	463	9.1	366	--	--	--	--	5.72	--	--	--	
5B	12/8	13.2 (105)	Vary OFA - Increase Air	955	9.5	136	9.0	362	--	--	--	--	5.72	--	--	--	
5C	12/8	13.2 (105)	Vary OFA - Further Increase Air	920	7.5	145	10.9	356	--	--	--	--	5.72	--	--	--	
5D	12/8	13.2 (105)	Vary OFA - Return to Normal	945	8.2	181	10.5	333	--	--	--	--	5.72	--	--	--	
6A	12/9	13.8 (109.5)	Vary OFA - Bias Top Row	978	7.7	378	10.4	333	--	--	--	--	7.72	--	--	--	
6D	12/9	13.8 (109.5)	Vary OFA - As Found	--	7.3	237	10.9	355	--	--	--	--	7.52	--	--	--	
6E	12/9	13.8 (109.5)	Vary OFA - Bias Top Row	--	7.2	313	10.9	352	8.1	209	10.2	412	7.52	--	--	859	Meter Out
7	12/10	12.9 (102)	Vary Grate Air, Normal O_2	980	7.5	176	10.5	355	8.2	227	10.3	362	6.49	--	--	1020	Meter Out
8	12/11	13.7 (108.5)	Max. O_2, Normal Operation	In 915 Out 1091	8.6	332	9.7	427	9.1	326	9.4	439	5.75	19.9	$\frac{18,146}{303}$ $\left(\frac{42.199}{0.7054}\right)$	934	Part In and Out; SOx In
9A	12/12	14.6 (111)	Vary Grate Air - As Found	880	7.4	280	10.6	392	--	--	--	--	5.8	--	--	--	
9B	12/12	14.0 (111)	Vary Grate Air - West Throttle, East Open	875	7.3	337	10.6	369	--	--	--	--	5.8	--	--	--	

(continued)

TABLE E-1. (continued)

Test No.	Date	Load kg/s (10^3 lb/hr)	Conditions	SO_2 Meter 3% O_2 ppm	CYCLONE INLET				CYCLONE OUTLET						Part ng/J (lb/MBtu) Out	SOx ppm	Notes
					O_2, %	CO ppm 3% O_2	CO_2 %	NO ppm 3% O_2	O_2, %	CO ppm 3% O_2	CO_2 %	NO ppm 3% O_2	kg Steam / kg Coal	% C in Ash			
WESTERN COAL - Continued																	
10	12/16/75	9.1 (72)	Normal O_2, Low Load	1020	9.5	262	9.4	338	--	--	--	--	5.73	12.2	$\frac{8,028}{186}$ $\left(\frac{10.67}{0.4315}\right)$	--	Part In and Out
11	12/17	10.4 (83)	Normal O_2, Low Load	1129	8.6	143	9.8	366	--	--	--	--	5.82	--	--	1146	SOx In
12	12/18	10.4 (82)	High O_2, Low Load	712	10.6	165	9.3	370	--	--	--	--	5.63	--	--	846	SOx In
13	12/19	10.2 (80)	High O_2, Low Load	770	9.9	198	9.0	302	--	--	--	--	5.70	13.3	$\frac{8,080}{290}$ $\left(\frac{10.79}{0.6754}\right)$	--	Part In and Out
14	12/20	9.9 (79)	Low O_2, Low Load	664	7.7	129	10.5	284	8.6	111	10.0	307	OOS	15.0	$\frac{5,803}{166}$ $\left(\frac{13.496}{0.3867}\right)$	--	Part In and Out
15	12/22	9.9 (79)	Low-Med. O_2, Low Load	736	8.2	234	10.4	344	--	--	--	--	5.72	--	--	815	SOx In
16	1/6/76	14.0 (111)	Low-Med. O_2, Low Load	937	6.6	1182	11.6	324	--	--	--	--	5.75	21.9	$\frac{4,657}{277}$ $\left(\frac{10.81}{0.6432}\right)$	849	Part In and Out; SOx In
17	1/7	15.9 (126)	Normal O_2, Maximum Load	1057	6.7	642	11.4	366	--	--	--	--	5.68	--	--	932	SOx In
18	1/8	16.1 (128)	Normal O_2, Maximum Load	963	6.0	2200	11.9	315	--	--	--	--	5.59	25.5	$\frac{12,234}{258}$ $\left(\frac{28.45}{0.6001}\right)$	--	Part In and Out
19	1/12	14.2 (113)	Low O_2, Medium Load	OOS	6.8	1221	11.4	343	7.85	876	11.4	356	5.58	--	--	878	SOx Out
20	1/13	14.5 (115)	Normal O_2, Medium Load	OOS	6.9	1003	OOS	374	8.3	1052	11.0	350	5.61	--	--	--	Complete Inlet and Outlet Gaseous
Average		12.9 (107.6)			7.9	504	10.36	359	8.39	467	10.34	376	5.98	18.14	258 (0.5996)	899	

trend with either boiler load or flue gas excess O_2. Indicated cyclone collection efficiencies were very high due to the questionable inlet particulate loadings. Assuming a cyclone efficiency of 85 percent one can back-calculate the inlet particulate loading of about 2252 ng/J (5.3 lb/10^6 Btu) which is a factor of 4 to 5 lower than the measured loading. Therefore the measured inlet loadings are considered to be unreliable. The problem is thought to be the sampling location rather than any procedural error in the sampling technique.

C. Nitric Oxide--

Nitric Oxide (NO) emissions measurements are given in Table E-1 for both coals. The overall average emission of NO was reduced approximately 18 percent by switching to western coal. Figures E-4 and E-5 contain the nitric oxide vs. O_2 data for Montana and Illinois coal respectively. Both data sets are at a medium load and both exhibit the expected trend of increasing NO with increasing excess O_2. The NO emissions from the Montana coal are all about 50 ppm lower than the NO emissions from the Illinois coal. This difference may be a result of differing fuel nitrogen content (Ill. = 1.35% fuel N, and Mont. = 0.68% fuel N) of the two coals; or it may be due to the high moisture content of the Montana coal which affects the combustion intensity (flame temperature) resulting in lower thermal fixation. The nitric oxide emissions were relatively constant with load for both coals.

D. Carbon Monoxide and Carbon Carryover--

The characteristic carbon monoxide emissions are given for Montana and Illinois coals in Figures E-6 and E-7 respectively. Both coals exhibit increasing CO emissions with increasing load. The quenching of the CO combustion is more extensive on Montana coal than on the Illinois coal. It has been demonstrated on other units, as well as this one, that CO emissions can be controlled by increasing the excess air. Inspection of the data in Table E-1 shows that when the excess O_2 is lowered to 6 percent, the CO emissions become significant. Comparing Tests 17 and 18, at the same load, demonstrated that increasing the excess O_2 by 0.7% reduced the CO from 2200 ppm to 642 ppm.

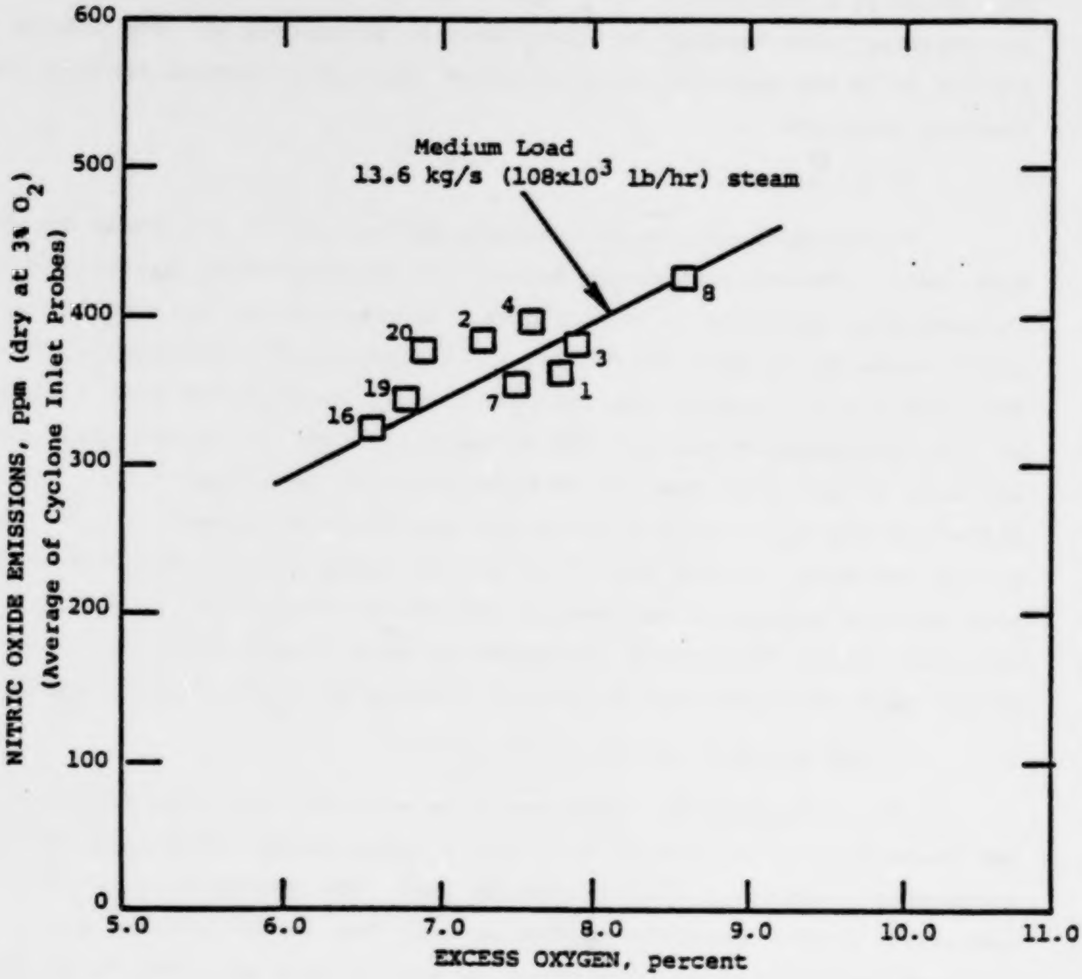

Figure E-4. Nitric oxide vs. excess oxygen, Unit 3, western coal.

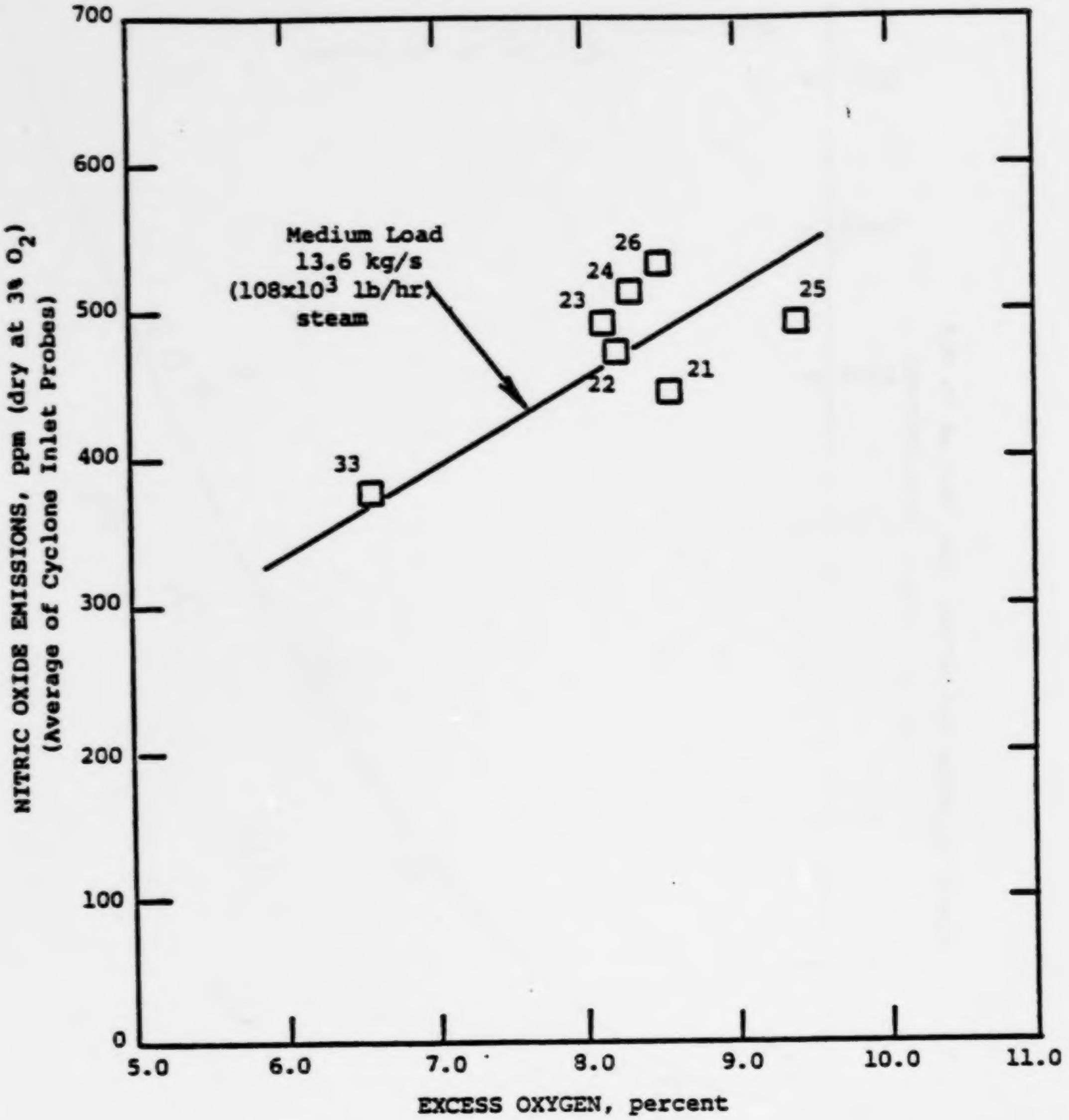

Figure E-5. Nitric oxide vs. excess oxygen, Unit 3, eastern coal.

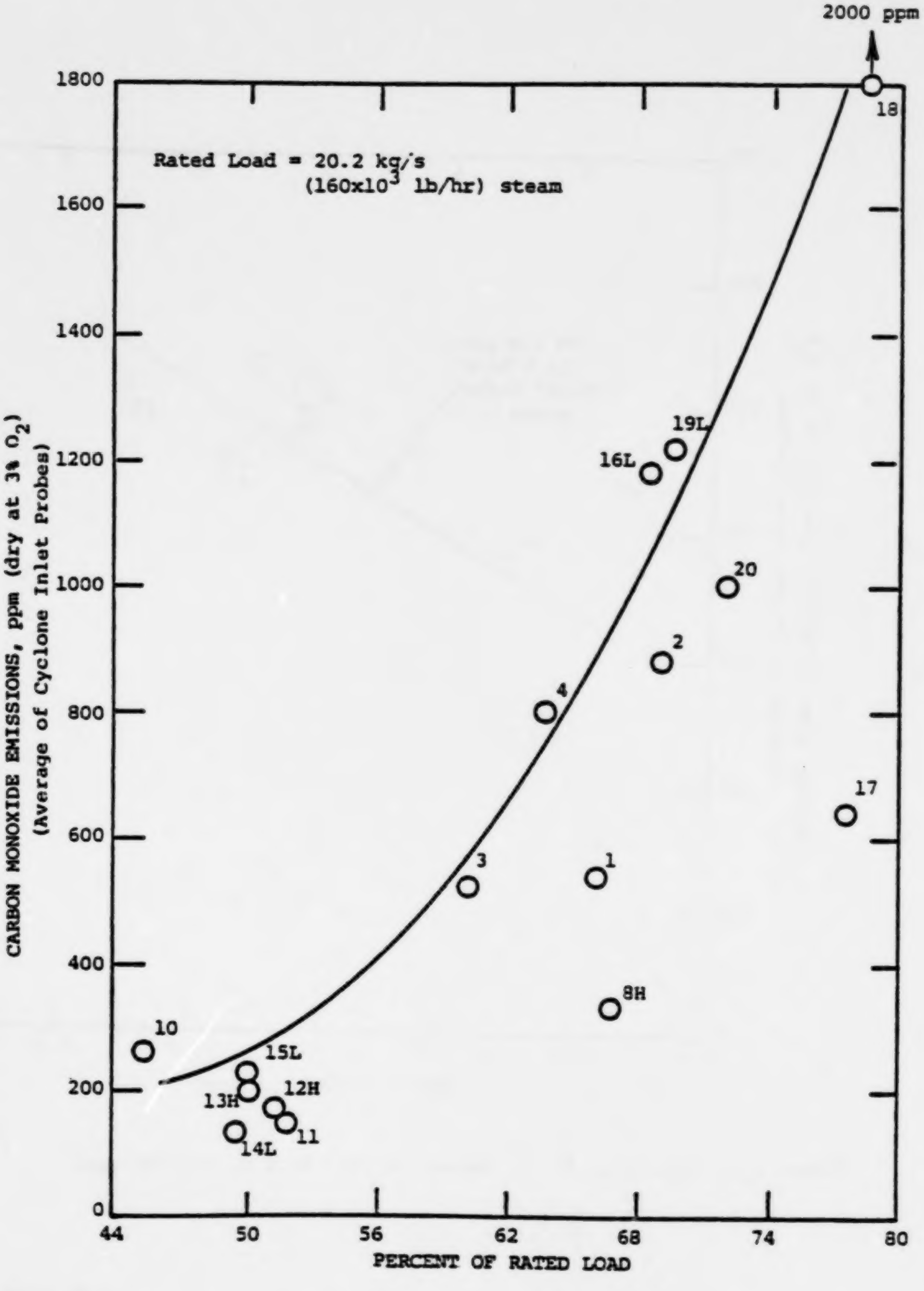

Figure E-6. Carbon monoxide vs. load, Unit 3, western coal.

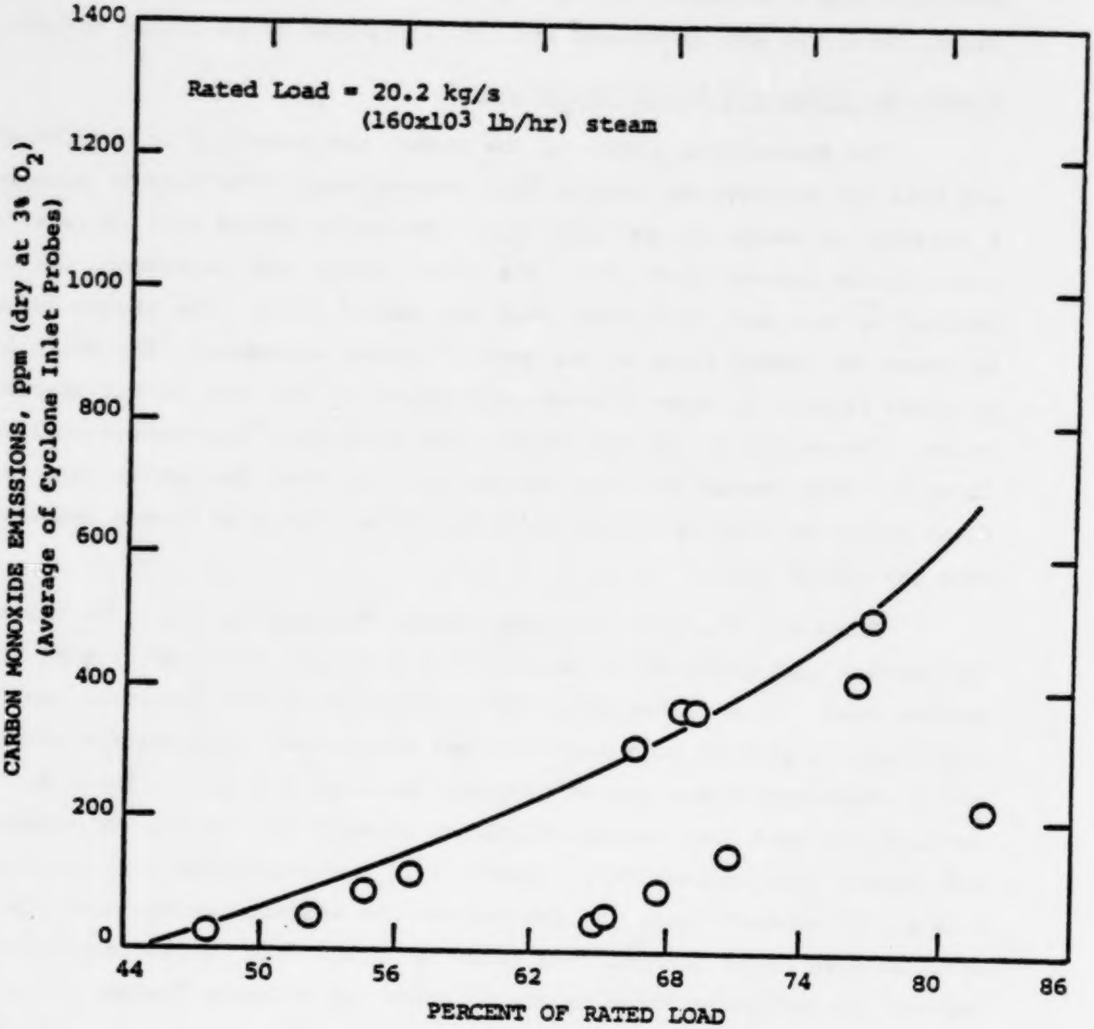

Figure E-7. Carbon monoxide vs. load, Unit 3, eastern coal.

Figures E-8 and E-9 contain the carbon carryover data as a function of load for western coal and eastern coal respectively. The western coal shows increasing carbon carryover with increasing load while the eastern coal data was a monotonic function of load. The magnitude of the eastern coal carbon carryover was approached only at high loads while firing western coal.

Stoker Operation and Boiler Efficiency

The operational limits of the stoker are presented in Figures E-10 and E-11 for western and eastern coal respectively. The data is plotted as a function of excess O_2 and unit load. The upper dashed line represents the limit of the induced draft fan. The lower dashed line represents the limit defined by fuel bed clinkering, high CO, and/or smoke. The region defined by these two dashed lines is the area of normal operation. The solid line on these figures is drawn through test points within this normal operating range. Comparison of the two solid lines shows that the western coal can be fired at lower excess air than the eastern coal over the entire load range. These plots may also be viewed as defining the limits of staged combustion in this particular unit.

Table E-1 contains a column labeled kg steam/kg coal. On the average the western coal produced 30 percent less steam per kilogram of coal than the eastern coal. This number gives some indication of how much more coal a plant would have to process to obtain the same steam load. However the actual boiler efficiencies are not so severely impaired as shown in Table E-2 which contains the heat loss boiler efficiency calculation results for eastern coal and western coal respectively. Tests 23-34 are on eastern coal and tests 3-18 are on western coal. On the average the western coal reduced the boiler efficiency by three percent from 80.9% to 78.5%. The largest differences between the two coals occur in the moisture and hydrogen losses. This, of course, is due to the high moisture content of the western coal. There are three factors which would cause loss of steam generation on western

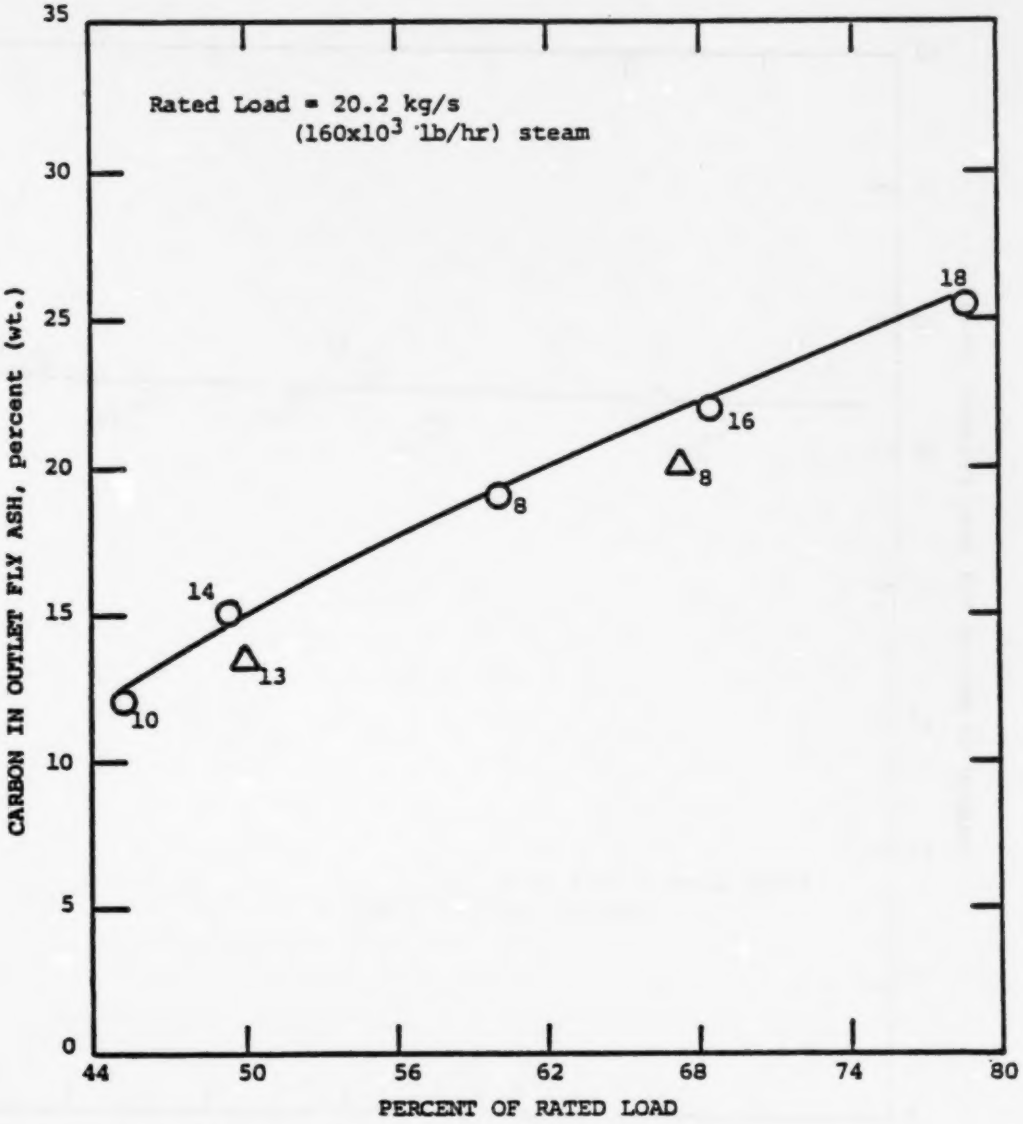

Figure E-8. Carbon vs. load, Unit 3, western coal.

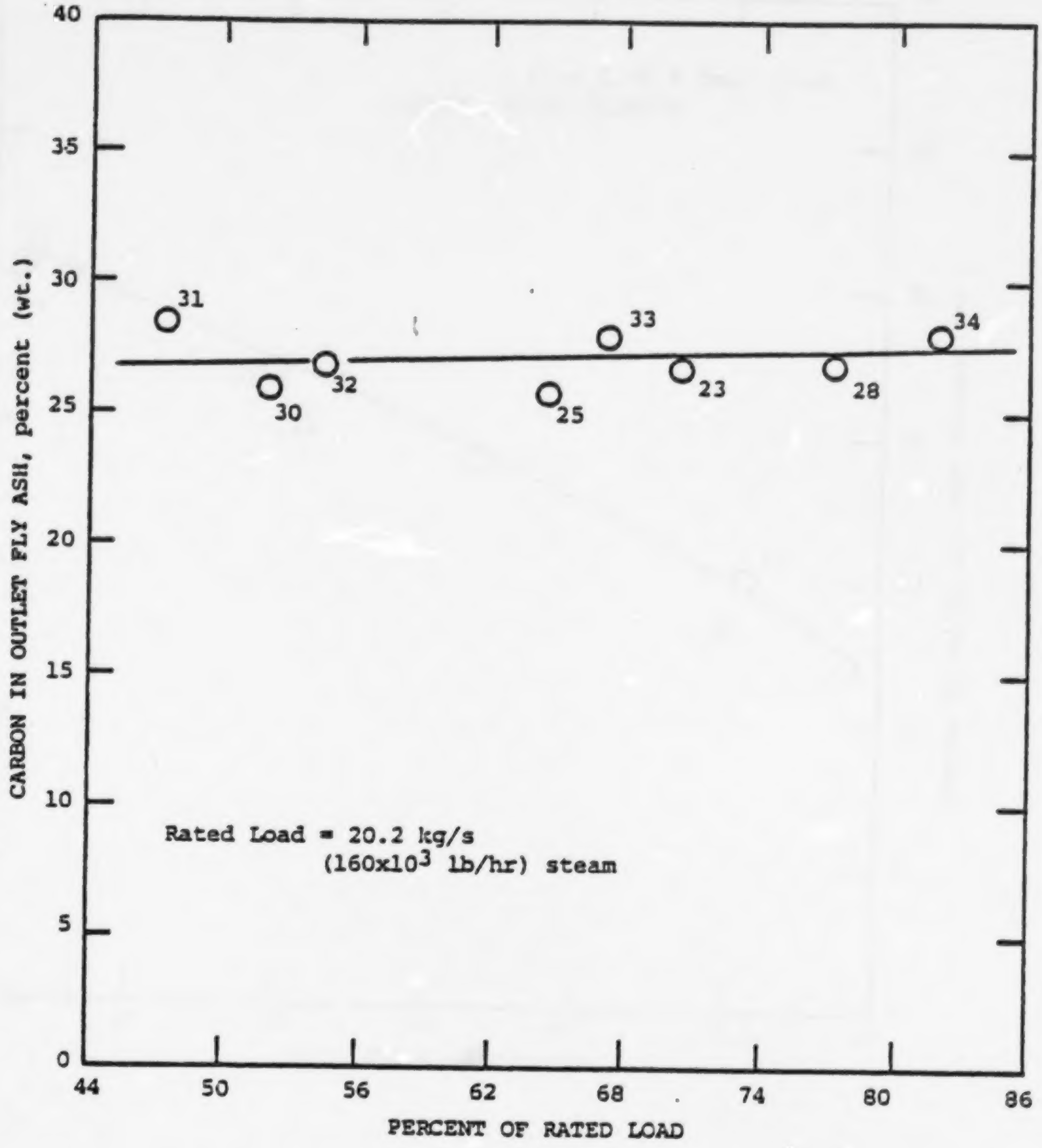

Figure E-9. Carbon vs. load, Unit 3, eastern coal.

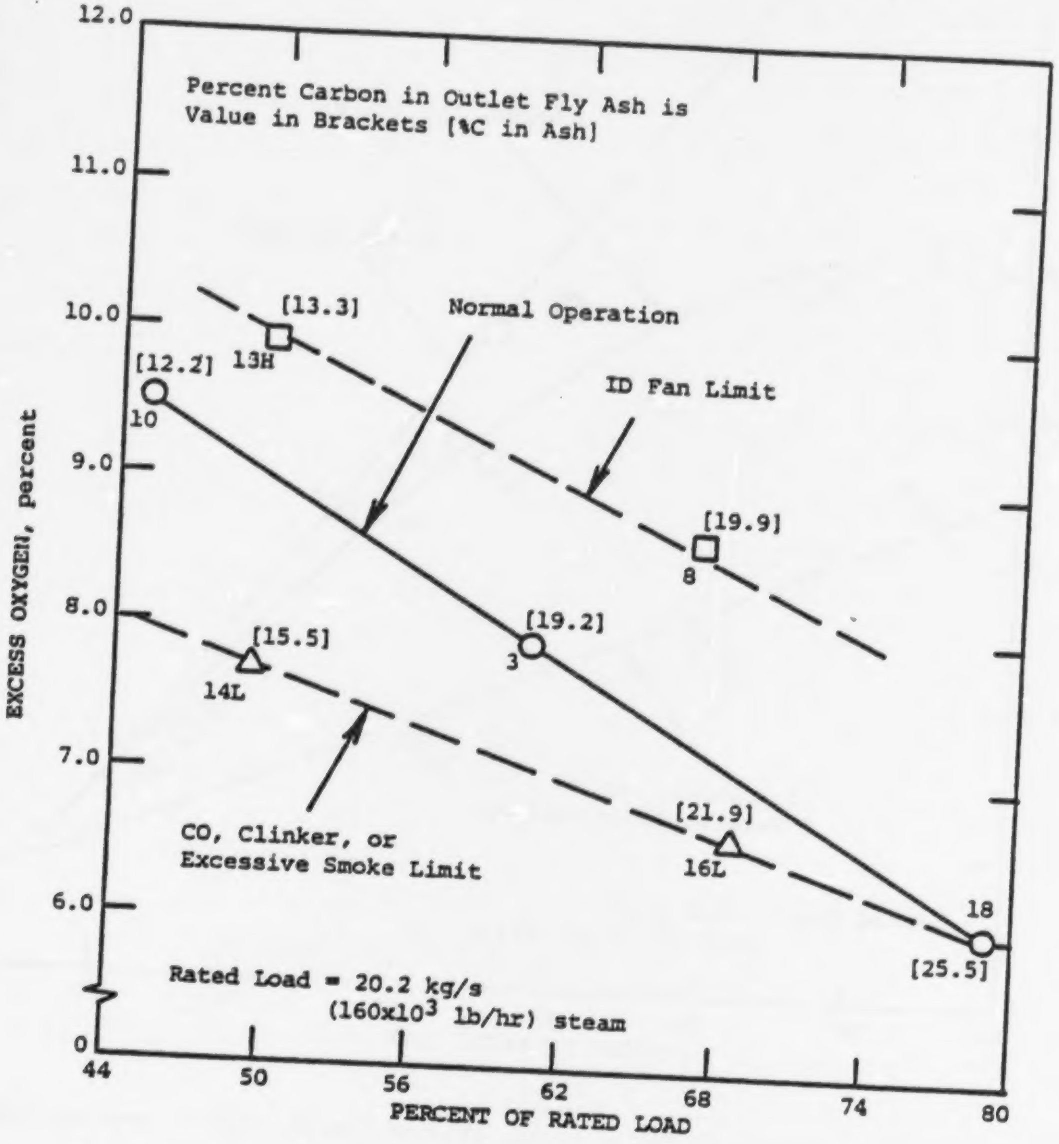

Figure E-10. Excess oxygen vs. load, staging limits, Unit 3, western coal.

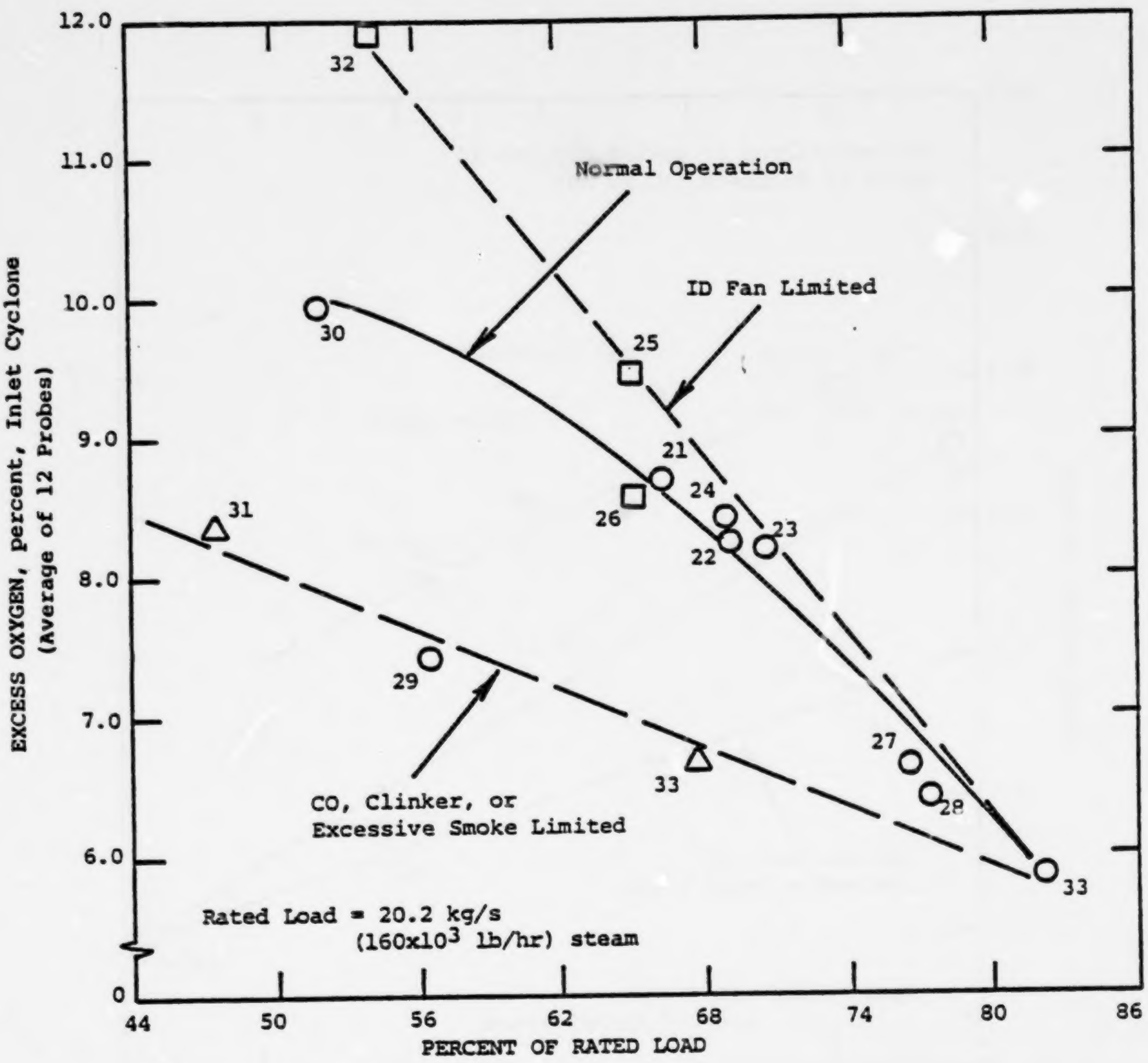

Figure E-11. Excess oxygen vs. load, staging limits, Unit 3, eastern coal.

TABLE E-2. CALCULATION OF EFFICIENCY

Boiler Category 312

Unit Description	
Location No.	4
Boiler No.	3
Furnace Type	WT
Capacity	
kg/s	20.2
10^3 lb/hr	160.0
MBtu/hr	285
Installed	1960
Erection Method	Field
Burner Type	SS

Eastern Coal Fuel Analysis	
C	69.26
H	4.73
O	7.47
N	1.37
S	2.28
H_2O	7.11
Ash	7.76
HHV/(Btu/lb)	12448
MJ/kg	28.9

BOILER CONDITIONS

Test No.	23	25	28	30	31	32	33	34
Test Load, % of Capacity	71.6	65.9	78.4	52.2	47.6	54.6	68.6	83.4
Stack O_2 (% Dry)	8.2	9.4	6.5	10.0	8.4	11.9	6.6	5.9
Stack CO (ppm)	146.0	44.0	509.0	51.0	26.0	84.0	89.0	216.0
Stack Temperature								
°K	484	491	484	473	469	472	500	489
°F	412.5	425.8	411.0	391.5	385.0	390.0	440.0	420.0
Ambient Air Temperature								
°K	302	305	300	303	308	299	301	299
°F	85.0	90.0	81.0	86.5	95.5	78.1	82.5	78.0
Calculated Air Heater Values, percent								
AH Inlet Excess Air	61.86	79.18	43.06	87.48	64.50	127.53	44.82	37.51
AH Exit Excess Air	74.72	106.86	52.86	100.92	75.73	137.34	53.97	50.68
Air Heater Leakage	7.49	14.65	6.51	6.82	6.45	4.14	5.92	8.94
Air Heater Efficiency	36.88	29.47	37.89	38.51	38.93	40.66	29.83	34.67
PCT. Air Through Air Heater	102.15	79.44	110.08	103.29	100.72	115.56	84.92	102.46
BOILER HEAT BALANCE LOSSES, percent								
Heat Balance Losses Corrected to 300 °K (80 °F) Entering Air Temperature								
Dry Gas	10.41	12.74	9.12	11.16	9.42	13.21	10.00	9.28
Moisture + H_2	4.93	4.95	4.93	4.89	4.87	4.89	4.98	4.95
Moisture in Air	0.25	0.31	0.22	0.27	0.23	0.32	0.24	0.22
Unburned CO	0.08	0.03	0.24	0.03	0.01	0.06	0.04	0.10
Combustibles	2.48	2.36	2.49	2.37	2.69	2.48	2.64	2.64
Radiation	0.56	0.61	0.51	0.77	0.84	0.73	0.58	0.48
Boiler Efficiency	81.30	79.01	82.49	80.52	81.94	78.30	81.52	82.34

(continued)

TABLE E-2. (continued).

Boiler Category 312

Unit Description	
Location No.	4
Boiler	3
Furnace Type	WT
Capacity	
kg/s	20.2
10^3 lb/hr	160.0
MBtu/hr	176.0
Installed	1960
Erection Method	Field
Burner Type	SS

Western Coal Fuel Analysis	
C	49.32
H	3.31
O	10.85
N	0.68
S	1.15
H_2O	25.56
Ash	9.12
HHV/(Btu/lb)	8408
MJ/kg	19.5

BOILER CONDITIONS

Test No.	3	8	10	13	14	16	18
Test Load, % of Capacity	60.9	67.8	45.0	50.0	49.4	69.4	80.0
Stack O_2 (% Dry)	7.9	8.6	9.5	9.9	7.7	6.6	6.0
Stack CO (ppm)	527.0	332.0	262.0	190.0	179.0	1182.0	2200.0
Stack Temperature							
°K	479	484	462	475	465	450	450
°F	402.0	412.0	373.0	395.0	378.0	351.0	351.0
Ambient Air Temperature							
°K	305	298	304	305	306	301	300
°F	90.0	77.0	88.0	90.0	91.0	82.0	80.0
Calculated Air Heater Values, percent							
AH Inlet Excess Air	59.0	67.85	80.84	87.28	56.65	44.83	39.12
AH Exit Excess Air	70.57	74.81	97.86	105.61	67.87	54.34	48.90
Air Heater Leakage	6.68	3.82	8.73	9.10	6.57	5.98	6.37
Air Heater Efficiency	38.18	38.38	39.10	36.87	40.29	47.80	49.19
PCT. Air Through Air Heater	100.23	113.73	105.20	99.17	107.30	134.98	143.06
BOILER HEAT BALANCE LOSSES, percent							
Heat Balance Losses Corrected to 300 °K (80 °F) Entering Air Temperature							
Dry Gas	9.88	10.61	10.52	11.73	9.04	7.54	7.22
Moisture + H_2	8.11	8.15	8.02	8.09	8.03	7.96	7.97
Moisture in Air	0.24	0.25	0.25	0.28	0.22	0.18	0.17
Unburned CO	0.28	0.18	0.16	0.13	0.09	0.56	0.99
Combustibles	2.80	2.93	1.64	1.81	2.08	3.31	4.04
Radiation	0.66	0.59	0.89	0.80	0.81	0.58	0.50
Boiler Efficiency	78.04	77.28	78.51	77.17	79.72	79.88	79.11

coal, they are: (1) limitation of maximum steam generation due to high superheat temperature, (in this case this limit resulted in a four percent reduction in maximum load); (2) limited coal handling and feeder capacity, (this was not a problem at this site); and (3) reduction in boiler efficiency due to increased moisture losses, (efficiency reductions of some three percent were measured when comparing western to eastern coal at comparable load and excess O_2's).

Eastern Coal Burning on Spreader Stoker

Unit 3 was designed to burn a high heat content eastern type coal. However, the Southern Illinois coal did not perform as well on the Montana coal. There were two reasons for the poor performance of the eastern coal. First, the test batch of eastern coal contained a large percentage of fines. Second, the overfire air fan was not functioning properly. The stoker developed a smoking problem and a Detroit Stoker factory representative was sent out to retune the stoker. The results of that effort are summarized below.

The boiler had a smoking problem when firing the Southern Illinois coal. The field representative from the stoker manufacturer noticed several problems with the boiler operation. First, the furnace draft was too low at -0.203 cm (-0.08 inches) of H_2O when it should have been almost twice that at -0.38 cm (-0.15 inches) H_2O. Second, the feeders on the stoker were out of adjustment in two ways. Both the hand wheels were out of adjustment and the spill plates were not set right. Third, the overfire air was not biased properly and not of sufficient pressure. After determining these three items, correction of the problem proceeded as follows.

First, all spill plates were reset to factory recommended setting of approximately 1.27 cm (1/2 inch). This adjustment is made by turning the spill plate adjusting screw clockwise all the way in until the center rib of the spill plate bears against the inner end of the screw. The adjusting screw was then backed off counter-clockwise until the 1.27 cm (1/2 inch) setting existed between the rib and inner end of the screw. This was done for all six feeders. Once the spill plates were set the hand wheels were readjusted.

To readjust the hand wheels, which control the feed rate, all the hand wheels were turned clockwise until they could not be tightened anymore. From this position, they were backed off from 1-1/2 to 2-1/2 turns counter-clockwise until a satisfactory fuel bed was formed, up and down the firing lane. From the 1-1/2 to 2-1/2 turn position the adjustment was made in 1/4 turn intervals. This concluded the fuel supply controls adjustment.

The overfire air was then reset. The first problem with this system was that the outlet of the blower was producing only 25.4 cm (10.0 inches) of H_2O pressure and it should have been about 68.6 cm (27 inches) of H_2O. A search for leaks in the overfire air system turned up none. Subsequent discussions with plant personnel revealed that the overfire air blower had been overhauled recently and closer inspection of the blower showed that the impeller had not been reinstalled properly. This reinstallation error resulted in insufficient "bite" by the impeller in the shroud to the fan and a resultant loss in air pressure. To compensate for the low fan capacity a blower from the adjacent unit #2 which was connected via a crossover duct was put in service. This additional fan raised the overfire air supply pressure to the required 68.6 cm (27 inches) of water pressure.

With sufficient air pressure restored to the overfire air system, the overfire air pressures were reset to factory specifications.

An overview of the overfire air settings were such that the back wall was at a higher pressure than the front wall. The back wall upper and lower rows were almost equal at about 43.2 cm (17 inches) H_2O pressure on the upper row and 41.4 cm (16.3 inches) H_2O pressure on the lower rear wall. On the front wall (feeder wall) the overall pressure was lower than the back wall. The upper and lower rows on the front wall were similarly biased. The lower row had about 38.1 cm (15 inches) of H_2O pressure, and only three to four inches on the top row on the front wall. This low pressure was just sufficient to keep the nozzles from heating up and did little to aid combustion. With most of the air through the lower jets the turbulence mixing immediately above the bed was increased. This resulted in increased residence time and improved carbon burnout.

This improved firing mode of the unit allowed the combustion air to be reduced which allowed the furnace draft to be increased. The final boiler configuration was a definite improvement over the initial condition of the stoker but still was not a complete solution to the smoking problem. Some smoking still existed and flue gas analyses of the excess O_2 distribution at the boiler outlet in a test (#34) immediately preceding the boiler tune-up revealed a high degree of stratification in the exhaust duct. This is shown in Table E-3 which presents the inlet cyclone flue gas distributions. The cyclone inlet is essentially the same as the boiler outlet. Also, shown in Table E-3 is a flue gas distribution from before the stoker tune up, this was test #23. The important thing to notice is the maldistribution of excess O_2 across the duct from east side to west side. For test 34 the average of east side probes (#1 though #6) is 4.98% excess O_2 and the west side probes (#7 through #12) average 6.79% O_2. A difference of 1.81% excess O_2 from east to west. Test 23's corresponding excess O_2 distribution is 6.69% for the east side and 9.58% for the west side. A change in excess O_2 of 2.89% from east to west. For test 34 the percentage variation of excess O_2 across the duct is 31% and for test 23 the percentage is 35%. The ultimate cause of the maldistribution of fuel and air was not discovered, even though a change in the smoking problem resulted.

Western coal burned better on the stoker. The eastern fuel had a tendency to form clinkers more readily than the western coal. This was probably due to the uneven fuel/air distribution which resulted in local cooling of the ash below its fusion temperature. The poor air/fuel distribution also caused the eastern fires to impinge on the back wall of the boiler. The western coal fires did not do this. Flame impingement and flame carryover into the superheat pendant section which caused slagging was more evident with the eastern than with the western coal. However, high superheat steam temperatures were a problem with western coal and some attemperation was required. Smoking was a continuous problem with the eastern coal firing. Interestingly enough, CO emissions tended to be higher for the western coal firing, yet smoke formation was not a problem as it was with eastern firing. The volatile matter to fixed carbon ration (vm/FC) is higher for eastern coal than for western coal resulting in a burnout problem on eastern coal.

TABLE E-3. FLUE GAS DISTRIBUTION BEFORE AND AFTER STOKER READJUSTMENT

TEST 34 - INLET CYCLONE - 83% load

	1	3	5	7	9	11	
O_2	4.8%	4.6%	4.7%	5.4%	6.55%	7.7%	
CO	278 ppm	258	364	213	69	54	
NO	333 ppm	316	309	312	354	337	
(East) Inlet Averages:	2	4	6	8	10	12	(West)
O_2 - 5.85%	4.85%	5.7%	5.2%	6.3%	7.3%	7.5%	
CO - 216	312	353	399	196	53	53	
NO - 336	331	308	321	331	374	333	

Outlet averages 7.2% O_2, 267 ppm CO, 326 ppm NO

Test 23 - Inlet Cyclone - 72% load

	1	3	5	7	9	11
O_2	6.0%	6.3%	7.45%	8.2%	9.48%	10.95%
CO	360	343	66	91	39	36
NO	444	453	494	534	539	546
Inlet Averages:	2	4	6	8	10	12
O_2 - 8.17%	5.87%	6.9%	7.6%	8.8%	9.3%	10.75%
CO - 145	357	243	87	59	38	35
NO - 491	438	466	500	528	548	558

Outlet averages 9.13% O_2, 177 ppm CO, 439 ppm NO

APPENDIX F

TABULATION OF HOURLY DATA

```
***********************************************************************
**                          24 HOUR DATA                            **
**                  DRY STACK GAS CONCENTRATION                     **
**                                                                  **
**                           O2      CO2      NO      NO      NO    **
**                   LOAD   VOL%    VOL%    PPMV    PPMV     NG/J   **
**   DATE     TIME   MWTH   MEAS    MEAS    MEAS    3%O2            **
***********************************************************************
** 8/11/79           24.6    9.3    10.1    252.    390.    229.    **
** 8/12/79           19.1   10.8     8.6    219.    389.    229.    **
** 8/13/79           21.7   10.0     9.6    225.    371.    218.    **
** 8/14/79           21.4   10.2     9.5    204.    341.    200.    **
** 8/15/79           21.2   10.5     9.2    224.    384.    225.    **
** 8/16/79           21.7    9.9     9.6    221.    360.    211.    **
** 8/17/79           23.0    9.5     9.7    230.    362.    212.    **
** 8/18/79           22.0    9.9     9.4    227.    369.    217.    **
** 8/19/79           18.3   10.8     8.3    222.    393.    231.    **
** 8/20/79           24.5    9.4     9.8    241.    374.    219.    **
** 8/21/79           24.0    9.2    10.0    220.    338.    198.    **
** 8/22/79           23.5    9.5     9.8    235.    368.    216.    **
** 8/23/79           21.7   10.4     8.9    206.    350.    206.    **
** 8/24/79           21.5    9.9     9.8    221.    358.    210.    **
** 8/25/79           19.5   10.5     9.1    208.    356.    209.    **
** 8/26/79           18.4   10.6     8.7    195.    340.    199.    **
** 8/27/79           22.9    9.9     9.6    231.    374.    220.    **
** 8/28/79           24.1    9.3     9.9    225.    348.    204.    **
** 8/29/79           25.9    9.1    10.4    245.    372.    218.    **
** 8/30/79           24.8    9.4    10.1    235.    366.    216.    **
** 8/31/79           26.8    8.7    10.7    239.    350.    206.    **
** 9/ 1/79           22.7    9.7     9.9    217.    348.    204.    **
** 9/ 2/79           18.5   10.5     9.1    207.    355.    208.    **
** 9/ 3/79           19.1   10.3     9.5    198.    333.    196.    **
** 9/ 4/79           27.2    8.8    10.8    238.    353.    207.    **
** 9/ 5/79           25.7    9.1    10.4    239.    363.    213.    **
** 9/ 6/79           23.4    9.7     9.9    223.    355.    208.    **
** 9/ 7/79           22.2    9.7     9.7    224.    358.    210.    **
** 9/ 8/79           19.8   10.1     9.1    231.    385.    226.    **
** 9/ 9/79           19.1   10.2     9.1    244.    407.    239.    **
** 9/10/79           23.8    9.4    10.1    241.    374.    220.    **
** 9/11/79           22.8    8.8    10.4    257.    382.    224.    **
** 9/12/79             .0   10.3     8.5    214.    359.    211.    **
***********************************************************************
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************************************************************
**                         HOURLY DATA                    **
**                  DRY STACK GAS CONCENTRATION           **
**                                                        **
**                         O2     CO2    NO     NO    NO  **
**                  LOAD   VOL%   VOL%   PPMV   PPMV  NG/J**
**   DATE    TIME   MWTH   MEAS   MEAS   MEAS   3%O2      **
************************************************************
** 0/ 0/79      0     .0     .0     .0     0.     0.    0.  **
** 0/ 0/79      0     .0     .0     .0     0.     0.    0.  **
** 0/ 0/79      0     .0     .0     .0     0.     0.    0.  **
** 0/ 0/79      0     .0     .0     .0     0.     0.    0.  **
** 0/ 0/79      0     .0     .0     .0     0.     0.    0.  **
** 0/ 0/79      0     .0     .0     .0     0.     0.    0.  **
** 0/ 0/79      0     .0     .0     .0     0.     0.    0.  **
** 0/ 0/79      0     .0     .0     .0     0.     0.    0.  **
** 0/ 0/79      0     .0     .0     .0     0.     0.    0.  **
** 0/ 0/79      0     .0     .0     .0     0.     0.    0.  **
** 0/ 0/79      0     .0     .0     .0     0.     0.    0.  **
** 8/11/79   1200   23.4    8.5   13.4   191.   276.  162.  **
** 8/11/79   1300   27.2    9.0   10.2   284.   427.  251.  **
** 8/11/79   1400   28.4    8.9   10.4   281.   419.  246.  **
** 8/11/79   1500   26.4    8.9   10.3   286.   427.  250.  **
** 8/11/79   1600   28.4    9.3   10.4   291.   449.  264.  **
** 8/11/79   1700   28.1    9.1   10.4   273.   414.  243.  **
** 8/11/79   1800   27.8    9.5   10.4   291.   457.  268.  **
** 8/11/79   1900   26.1    9.6   10.4   302.   478.  281.  **
** 8/11/79   2000   28.4    8.6   10.8   282.   410.  241.  **
** 8/11/79   2100   19.0    9.2    8.9   190.   291.  171.  **
** 8/11/79   2200   17.9    9.6    9.0   199.   315.  185.  **
** 8/11/79   2300   17.0   10.5    8.3   201.   346.  203.  **
** 8/11/79   2400   17.9   10.6    8.3   203.   353.  207.  **
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**                            HOURLY DATA                              **
**                   DRY STACK GAS CONCENTRATION                       **
**                                                                     **
**                                O2      CO2     NO      NO     NO    **
**                        LOAD    VOL%    VOL%    PPMV    PPMV   NG/J  **
**   DATE        TIME     MWTH    MEAS    MEAS    MEAS    3%O2         **
*************************************************************************
** 8/12/79        100     19.0    10.5    8.8     229.    394.   231.  **
** 8/12/79        200     18.5    10.9    8.5     226.    405.   238.  **
** 8/12/79        300     17.3    11.4    8.1     216.    407.   239.  **
** 8/12/79        400     17.0    11.5    8.1     215.    409.   240.  **
** 8/12/79        500     17.6    11.5    8.1     207.    394.   231.  **
** 8/12/79        600     17.0    11.7    7.9     211.    411.   241.  **
** 8/12/79        700     16.7    11.7    7.9     204.    397.   233.  **
** 8/12/79        800     17.3    11.5    8.1     208.    396.   233.  **
** 8/12/79        900     19.3    11.1    8.5     217.    396.   233.  **
** 8/12/79       1000     16.8    10.7    8.7     206.    362.   212.  **
** 8/12/79       1100     20.8    10.1    9.4     230.    381.   224.  **
** 8/12/79       1200     19.6    10.4    9.1     212.    361.   212.  **
** 8/12/79       1300     20.2    10.2    9.3     208.    348.   204.  **
** 8/12/79       1400     19.9    10.5    8.9     196.    337.   198.  **
** 8/12/79       1500     19.0    10.5    8.9     208.    358.   210.  **
** 8/12/79       1600     18.8    10.6    8.8     211.    367.   215.  **
** 8/12/79       1700     19.0    10.6    8.8     228.    396.   233.  **
** 8/12/79       1800     16.2    10.8    8.6     225.    399.   234.  **
** 8/12/79       1900     17.9    10.9    8.5     227.    406.   239.  **
** 8/12/79       2000     18.2    10.7    8.7     230.    404.   237.  **
** 8/12/79       2100     19.9    10.5    8.8     236.    406.   238.  **
** 8/12/79       2200     21.4    10.0    9.4     255.    419.   246.  **
** 8/12/79       2300     21.1    10.2    9.2     240.    401.   236.  **
** 8/12/79       2400     20.4    11.0    8.3     221.    400.   235.  **
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**                      HOURLY DATA                       **
**               DRY STACK GAS CONCENTRATION              **
**                                                        **
**                          O2     CO2    NO     NO    NO **
**                   LOAD   VOL%   VOL%   PPMV   PPMV  NG/J **
**    DATE    TIME   MWTH   MEAS   MEAS   MEAS   3%O2     **
************************************************************
** 8/13/79    100   27.8   11.0    8.3   226.   409.  240. **
** 8/13/79    200   28.7   10.6    8.8   240.   417.  245. **
** 8/13/79    300   28.1   10.8    8.6   230.   408.  239. **
** 8/13/79    400   27.8   10.7    8.8   230.   404.  237. **
** 8/13/79    500   28.1   10.4    9.1   219.   373.  219. **
** 8/13/79    600   26.4   10.4    9.1   239.   407.  239. **
** 8/13/79    700   24.9   11.2    8.2   210.   388.  228. **
** 8/13/79    800   24.3   10.2    9.5   234.   391.  230. **
** 8/13/79    900   22.9   11.0    8.4   212.   383.  225. **
** 8/13/79   1000   21.4    9.2   10.1   247.   378.  222. **
** 8/13/79   1100   22.0    9.1   10.6   243.   369.  216. **
** 8/13/79   1200   20.5    8.9   10.9   223.   333.  195. **
** 8/13/79   1300   19.9    8.5   11.3   217.   313.  184. **
** 8/13/79   1400   17.6    8.5   11.3   224.   323.  190. **
** 8/13/79   1500   17.3    8.6   11.3   230.   335.  197. **
** 8/13/79   1600   18.5    9.3   10.6   234.   361.  212. **
** 8/13/79   1700   18.2    9.3   10.5   242.   373.  219. **
** 8/13/79   1800   18.5    9.7   10.0   247.   395.  232. **
** 8/13/79   1900   19.0    9.9    9.8   244.   397.  233. **
** 8/13/79   2000   19.6   10.2    9.4   235.   393.  231. **
** 8/13/79   2100   18.2   10.1    9.5   206.   341.  200. **
** 8/13/79   2200   17.6   10.8    8.8   202.   358.  210. **
** 8/13/79   2300   17.6   10.8    8.8   199.   353.  207. **
** 8/13/79   2400   17.0   11.7    7.8   176.   342.  201. **
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**                          HOURLY DATA                             **
**                  DRY STACK GAS CONCENTRATION                     **
**                                                                  **
**                           O2       CO2      NO      NO      NO   **
**                  LOAD     VOL%     VOL%     PPMV    PPMV    NG/J **
**   DATE    TIME   MWTH     MEAS     MEAS     MEAS    3%O2         **
**********************************************************************
** 8/14/79    100   18.5     11.0      8.7     195.    353.    207.  **
** 8/14/79    200   19.0     10.7      9.0     209.    367.    215.  **
** 8/14/79    300   18.8     11.1      8.5     193.    353.    207.  **
** 8/14/79    400   19.0     10.7      8.9     196.    344.    202.  **
** 8/14/79    500   19.3     10.6      9.1     193.    335.    197.  **
** 8/14/79    600   19.6     10.6      9.2     202.    351.    206.  **
** 8/14/79    700   17.3     11.4      8.3     180.    339.    199.  **
** 8/14/79    800   17.6     11.2      8.4     176.    325.    191.  **
** 8/14/79    900   21.1      9.9      9.7     190.    309.    182.  **
** 8/14/79   1000   24.9      9.1     10.6     241.    366.    215.  **
** 8/14/79   1100   27.5      8.6     11.1     234.    341.    200.  **
** 8/14/79   1200   27.8      8.3     11.3     213.    303.    178.  **
** 8/14/79   1300   25.2      9.3     10.5     204.    315.    185.  **
** 8/14/79   1400   24.6      9.0     10.7     194.    292.    171.  **
** 8/14/79   1500   25.5      9.0     10.8     214.    322.    189.  **
** 8/14/79   1600   24.9      9.5     10.3     214.    336.    197.  **
** 8/14/79   1700   24.3      9.5     10.2     209.    328.    193.  **
** 8/14/79   1800   22.0     10.0      9.8     210.    345.    202.  **
** 8/14/79   1900   20.5     10.5      9.3     206.    355.    208.  **
** 8/14/79   2000   19.6     10.9      8.9     197.    353.    207.  **
** 8/14/79   2100   19.9     10.8      9.0     199.    353.    207.  **
** 8/14/79   2200   20.2     10.7      9.1     212.    372.    218.  **
** 8/14/79   2300   17.6     10.7      9.1     216.    379.    223.  **
** 8/14/79   2400   17.6     11.8      7.8     196.    386.    226.  **
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**                            HOURLY DATA                             **
**                      DRY STACK GAS CONCENTRATION                   **
**                                                                    **
**                              O2     CO2      NO      NO       NO   **
**                    LOAD    VOL%    VOL%    PPMV    PPMV     NG/J   **
**   DATE      TIME   MWTH    MEAS    MEAS    MEAS    3%O2            **
************************************************************************
** 8/15/79      100   17.6    10.9     8.7    217.    388.     228.   **
** 8/15/79      200   17.3    11.4     8.3    212.    399.     235.   **
** 8/15/79      300   18.2    11.6     8.0    209.    402.     236.   **
** 8/15/79      400   17.0    11.6     8.1    213.    410.     241.   **
** 8/15/79      500   18.5    11.5     8.2    212.    404.     237.   **
** 8/15/79      600   20.5    11.4     8.2    219.    413.     242.   **
** 8/15/79      700   23.7    11.5     8.2    224.    427.     250.   **
** 8/15/79      800   24.9    11.2     8.5    230.    424.     249.   **
** 8/15/79      900   25.8    10.2     9.4    253.    423.     249.   **
** 8/15/79     1000   26.1     9.5    10.1    254.    399.     234.   **
** 8/15/79     1100   26.1     9.4    10.3    249.    388.     228.   **
** 8/15/79     1200   26.1     9.2    10.4    242.    370.     217.   **
** 8/15/79     1300   24.9     9.3    10.3    236.    364.     214.   **
** 8/15/79     1400   24.9     9.4    10.3    227.    353.     207.   **
** 8/15/79     1500   24.0     9.4    10.3    244.    380.     223.   **
** 8/15/79     1600   21.1     9.5    10.2    245.    385.     226.   **
** 8/15/79     1700   20.2     9.5    10.2    253.    397.     233.   **
** 8/15/79     1800   19.9    10.0     9.7    240.    394.     231.   **
** 8/15/79     1900   20.2    10.4     9.2    219.    373.     219.   **
** 8/15/79     2000   19.3    10.6     8.9    209.    363.     213.   **
** 8/15/79     2100   18.2    10.4     9.1    198.    338.     198.   **
** 8/15/79     2200   17.6    10.7     8.8    200.    351.     206.   **
** 8/15/79     2300   18.8    10.9     8.5    192.    344.     202.   **
** 8/15/79     2400   17.9    11.5     7.8    179.    341.     200.   **
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**                           HOURLY DATA                            **
**                 DRY STACK GAS CONCENTRATION                      **
**                                                                  **
**                                                                  **
**                              O2      CO2     NO      NO          **
**                      LOAD    VOL%    VOL%    PPMV    PPMV   NO   **
**   DATE       TIME    MWTH    MEAS    MEAS    MEAS    3%O2   NG/J **
**********************************************************************
** 8/16/79       100    17.3    10.7     8.8    198.    347.   204. **
** 8/16/79       200    17.6    10.9     8.5    198.    354.   208. **
** 8/16/79       300    18.2    11.2     8.1    199.    367.   216. **
** 8/16/79       400    18.2    10.9     8.4    212.    379.   223. **
** 8/16/79       500    18.5    10.7     8.6    213.    374.   219. **
** 8/16/79       600    17.9    10.7     8.7    229.    402.   236. **
** 8/16/79       700    19.0    11.0     8.4    216.    391.   229. **
** 8/16/79       800    21.7    10.7     8.6    214.    376.   220. **
** 8/16/79       900    24.0     9.7    10.4    220.    352.   206. **
** 8/16/79      1000    25.8     9.1    11.2    237.    360.   211. **
** 8/16/79      1100    26.4     8.9    10.7    229.    342.   201. **
** 8/16/79      1200    24.9     8.8    10.7    219.    324.   190. **
** 8/16/79      1300    27.2     8.9    10.7    206.    307.   180. **
** 8/16/79      1400    26.1     8.8    10.7    230.    340.   200. **
** 8/16/79      1500    26.7     9.0    10.5    230.    346.   203. **
** 8/16/79      1600    24.6     9.0    10.6    236.    355.   208. **
** 8/16/79      1700    24.0     9.3    10.3    236.    364.   214. **
** 8/16/79      1800    23.4     9.5    10.1    239.    375.   220. **
** 8/16/79      1900    22.6     9.7     9.9    235.    376.   220. **
** 8/16/79      2000    22.6     9.7     9.7    233.    372.   221. **
** 8/16/79      2100    19.9     9.7     9.6    217.    347.   219. **
** 8/16/79      2200    19.3    10.1     9.3    224.    371.   204. **
** 8/16/79      2300    16.1    10.3     9.1    223.    377.   218. **
** 8/16/79      2400    18.8    11.0     8.3    200.    362.   221. **
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**                                                                **
**                         HOURLY DATA                            **
**                DRY STACK GAS CONCENTRATION                     **
**                                                                **
**                          O2       CO2      NO      NO          **
**                  LOAD    VOL%     VOL%     PPMV    PPMV   NO   **
**   DATE     TIME  MWTH    MEAS     MEAS     MEAS    3%O2   NG/J **
********************************************************************
** 8/17/79     100  17.6    10.3      9.1     229.    387.   227. **
** 8/17/79     200  17.9    10.8      8.6     208.    369.   216. **
** 8/17/79     300  17.6    11.2      8.1     200.    369.   217. **
** 8/17/79     400  17.6    10.9      8.4     205.    367.   215. **
** 8/17/79     500  17.9    10.6      8.7     203.    353.   207. **
** 8/17/79     600  19.9    10.5      8.8     223.    384.   225. **
** 8/17/79     700  19.6    10.6      8.7     224.    389.   229. **
** 8/17/79     800  20.2    10.5      8.8     224.    386.   226. **
** 8/17/79     900  23.4     9.3     10.0     256.    395.   232. **
** 8/17/79    1000  26.4     8.8     10.5     271.    401.   235. **
** 8/17/79    1100  28.1     8.5     10.8     274.    396.   232. **
** 8/17/79    1200  29.0     8.3     11.0     259.    368.   216. **
** 8/17/79    1300  28.1     8.4     10.9     238.    341.   200. **
** 8/17/79    1400  29.9     8.1     11.1     225.    315.   185. **
** 8/17/79    1500  29.0     8.3     11.0     239.    340.   199. **
** 8/17/79    1600  27.5     8.5     10.8     238.    344.   202. **
** 8/17/79    1700  26.7     8.7     10.6     239.    351.   206. **
** 8/17/79    1800  24.3     9.0     10.3     236.    355.   208. **
** 8/17/79    1900  22.6     9.3      9.9     229.    353.   207. **
** 8/17/79    2000  22.0     9.5      9.8     228.    358.   210. **
** 8/17/79    2100  22.0     9.4      9.8     218.    339.   199. **
** 8/17/79    2200  22.3     9.4      9.8     232.    361.   212. **
** 8/17/79    2300  22.0     9.5      9.7     222.    349.   205. **
** 8/17/79    2400  19.9    10.3      8.8     197.    333.   195. **
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**                              HOURLY DATA                             **
**                      DRY STACK GAS CONCENTRATION                     **
**                                                                      **
**                                                                      **
**                              O2      CO2      NO      NO      NO     **
**                     LOAD    VOL%    VOL%     PPMV    PPMV    NG/J    **
**   DATE      TIME    MWTH    MEAS    MEAS     MEAS    3%O2            **
**************************************************************************
** 8/18/79      100    19.0    10.2     8.9     204.    341.    200.    **
** 8/18/79      200    20.2    10.2     8.9     212.    355.    208.    **
** 8/18/79      300    18.8    10.3     8.7     207.    350.    205.    **
** 8/18/79      400    17.9    10.5     8.5     204.    351.    206.    **
** 8/18/79      500    17.9    10.5     8.5     195.    336.    197.    **
** 8/18/79      600    17.9    10.5     8.5     207.    356.    209.    **
** 8/18/79      700    18.5    10.3     8.7     213.    360.    211.    **
** 8/18/79      800    17.9    10.5     8.5     222.    382.    224.    **
** 8/18/79      900    19.9    10.2     8.8     218.    365.    214.    **
** 8/18/79     1000    22.3     9.5     9.6     231.    363.    213.    **
** 8/18/79     1100    25.5     9.0    10.1     212.    319.    187.    **
** 8/18/79     1200    26.4     9.0    10.0     212.    319.    187.    **
** 8/18/79     1300    27.0     9.0    10.4     214.    322.    189.    **
** 8/18/79     1400    27.5     8.9    10.5     209.    312.    183.    **
** 8/18/79     1500    27.0     9.1    10.4     235.    356.    209.    **
** 8/18/79     1600    26.1     9.4    10.2     250.    389.    228.    **
** 8/18/79     1700    24.9     9.5    10.1     261.    410.    241.    **
** 8/18/79     1800    24.6     9.6    10.0     264.    418.    246.    **
** 8/18/79     1900    23.4     9.7     9.8     261.    417.    245.    **
** 8/18/79     2000    22.6     9.9     9.6     257.    418.    246.    **
** 8/18/79     2100    22.0    10.1     9.4     245.    406.    238.    **
** 8/18/79     2200    22.0    10.0     9.5     250.    411.    241.    **
** 8/18/79     2300    20.2    10.6     8.9     237.    412.    242.    **
** 8/18/79     2400    19.0    10.7     8.7     231.    405.    238.    **
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*****************************************************************
**                         HOURLY DATA                         **
**                  DRY STACK GAS CONCENTRATION                **
**                                                             **
**                          O2      CO2     NO     NO     NO   **
**                   LOAD   VOL%    VOL%    PPMV   PPMV   NG/J **
**   DATE     TIME   MWTH   MEAS    MEAS    MEAS   3%O2        **
*****************************************************************
** 8/19/79     100   18.8   10.7     8.6    232.   407.   239. **
** 8/19/79     200   18.8   11.0     8.3    222.   401.   236. **
** 8/19/79     300   16.7   11.3     7.9    215.   401.   235. **
** 8/19/79     400   16.1   11.4     7.7    211.   398.   233. **
** 8/19/79     500   16.1   11.6     7.4    197.   379.   223. **
** 8/19/79     600   16.1   11.4     7.5    207.   390.   229. **
** 8/19/79     700   17.3   11.0     8.1    218.   394.   231. **
** 8/19/79     800   17.6   11.0     8.1    225.   407.   239. **
** 8/19/79     900   18.5   10.9     8.2    224.   401.   235. **
** 8/19/79    1000   16.7   11.1     8.0    219.   400.   235. **
** 8/19/79    1100   18.8   10.8     8.4    228.   404.   237. **
** 8/19/79    1200   19.3   10.6     8.7    233.   405.   238. **
** 8/19/79    1300   19.6   10.6     8.8    231.   401.   236. **
** 8/19/79    1400   19.6   10.5     8.8    218.   375.   220. **
** 8/19/79    1500   19.0   10.6     8.6    226.   393.   231. **
** 8/19/79    1600   18.5   10.7     8.4    226.   397.   233. **
** 8/19/79    1700   18.2   10.7     8.3    224.   393.   231. **
** 8/19/79    1800   18.5   10.6     8.4    222.   386.   227. **
** 8/19/79    1900   18.2   10.7     8.3    221.   388.   228. **
** 8/19/79    2000   18.5   10.7     8.4    225.   395.   232. **
** 8/19/79    2100   19.6   10.3     8.8    225.   380.   223. **
** 8/19/79    2200   20.8   10.1     9.0    238.   394.   232. **
** 8/19/79    2300   19.0   10.6     8.4    217.   377.   221. **
** 8/19/79    2400   16.8   10.7     8.3    214.   376.   220. **
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**                      HOURLY DATA                     **
**              DRY STACK GAS CONCENTRATION             **
**                                                      **
**                          O2    CO2     NO     NO     NO **
**                  LOAD  VOL%   VOL%   PPMV   PPMV   NG/J **
**  DATE     TIME   MWTH  MEAS   MEAS   MEAS   3%O2        **
**********************************************************
** 8/20/79    100   19.0  10.5    8.5   226.   389.   228.  **
** 8/20/79    200   18.5  10.7    8.3   216.   379.   223.  **
** 8/20/79    300   17.3  10.8    8.0   201.   356.   209.  **
** 8/20/79    400   16.7  10.9    7.8   191.   342.   201.  **
** 8/20/79    500   17.6  10.7    8.1   193.   339.   199.  **
** 8/20/79    600   18.5  10.5    8.3   208.   358.   210.  **
** 8/20/79    700   19.0  10.3    8.5   213.   360.   211.  **
** 8/20/79    800   21.1   9.6    9.9   230.   364.   214.  **
** 8/20/79    900   24.9   9.9    9.2   230.   374.   220.  **
** 8/20/79   1000   27.8   8.8   10.7   299.   442.   260.  **
** 8/20/79   1100   30.8   8.5   11.0   310.   447.   263.  **
** 8/20/79   1200   33.1   8.0   11.4   299.   415.   244.  **
** 8/20/79   1300   32.5   8.2   11.2   300.   423.   248.  **
** 8/20/79   1400   33.4   7.9   11.4   261.   359.   211.  **
** 8/20/79   1500   31.1   8.3   11.0   242.   344.   202.  **
** 8/20/79   1600   30.2   8.2   11.1   254.   358.   210.  **
** 8/20/79   1700   28.1   8.4   11.0   254.   364.   214.  **
** 8/20/79   1800   27.2   8.5   10.9   253.   365.   214.  **
** 8/20/79   1900   26.1   8.7   10.6   255.   374.   220.  **
** 8/20/79   2000   25.5   8.8   10.6   248.   367.   215.  **
** 8/20/79   2100   24.9   9.1   10.2   244.   370.   217.  **
** 8/20/79   2200   22.6   9.5    9.8   232.   364.   214.  **
** 8/20/79   2300   22.6   9.6    9.7   221.   350.   206.  **
** 8/20/79   2400   19.0  10.4    8.7   201.   343.   201.  **
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*****************************************************************
**                     HOURLY DATA                             **
**             DRY STACK GAS CONCENTRATION                     **
**                                                             **
**                          O2      CO2     NO     NO     NO   **
**                   LOAD   VOL%    VOL%    PPMV   PPMV   NG/J **
**  DATE      TIME   MWTH   MEAS    MEAS    MEAS   3%O2        **
*****************************************************************
** 8/21/79     100   16.7   10.3     8.7    208.   351.   206. **
** 8/21/79     200   16.4   10.9     8.0    192.   344.   202. **
** 8/21/79     300   15.8   11.1     7.8    186.   340.   199. **
** 8/21/79     400   17.6   10.5     8.5    206.   355.   208. **
** 8/21/79     500   18.5   10.3     8.7    191.   323.   189. **
** 8/21/79     600   18.5   10.3     8.7    196.   331.   194. **
** 8/21/79     700   19.0   10.2     8.9    197.   330.   193. **
** 8/21/79     800   21.1   10.0     9.1    207.   340.   200. **
** 8/21/79     900   24.9    8.9    10.4    233.   348.   204. **
** 8/21/79    1000   29.3    8.2    11.2    239.   337.   198. **
** 8/21/79    1100   33.1    7.6    11.7    224.   301.   177. **
** 8/21/79    1200   31.9    8.1    11.3    217.   303.   178. **
** 8/21/79    1300   29.3    8.3    11.1    221.   314.   184. **
** 8/21/79    1400   30.2    7.8    11.5    221.   302.   177. **
** 8/21/79    1500   29.6    8.4    11.0    243.   346.   204. **
** 8/21/79    1600   29.3    8.1    11.3    242.   338.   199. **
** 8/21/79    1700   28.1    8.4    11.0    241.   345.   203. **
** 8/21/79    1800   27.2    8.6    10.7    233.   339.   199. **
** 8/21/79    1900   24.9    8.9    10.4    230.   343.   201. **
** 8/21/79    2000   24.0    9.1    10.2    242.   367.   216. **
** 8/21/79    2100   24.6    9.0    10.2    238.   358.   210. **
** 8/21/79    2200   23.4    9.2    10.0    237.   363.   213. **
** 8/21/79    2300   22.9    9.3     9.9    230.   355.   208. **
** 8/21/79    2400   20.2   10.2     8.8    205.   343.   201. **
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**                         HOURLY DATA                              **
**                DRY STACK GAS CONCENTRATION                       **
**                                                                  **
**                            O2      CO2      NO      NO      NO   **
**                   LOAD    VOL%    VOL%     PPMV    PPMV    NG/J  **
**   DATE     TIME   MWTH    MEAS    MEAS     MEAS    3%O2          **
**********************************************************************
** 8/22/79     100   19.0    10.1     8.9     213.    353.    207.  **
** 8/22/79     200   18.2    10.4     8.5     215.    367.    215.  **
** 8/22/79     300   17.3    10.6     8.2     212.    368.    216.  **
** 8/22/79     400   16.7    10.7     8.0     207.    363.    213.  **
** 8/22/79     500   16.1    10.9     7.9     202.    362.    212.  **
** 8/22/79     600   16.7    10.7     8.0     196.    344.    202.  **
** 8/22/79     700   20.5    10.0     8.9     215.    353.    207.  **
** 8/22/79     800   20.5    10.1     8.8     207.    343.    201.  **
** 8/22/79     900   23.4     9.2    10.3     220.    337.    198.  **
** 8/22/79    1000   26.1     8.8    10.6     246.    364.    214.  **
** 8/22/79    1100   27.8     8.7    10.7     253.    371.    218.  **
** 8/22/79    1200   29.0     8.6    10.9     244.    355.    208.  **
** 8/22/79    1300   27.8     8.5    11.0     233.    336.    197.  **
** 8/22/79    1400   29.3     8.4    11.1     238.    341.    200.  **
** 8/22/79    1500   28.1     8.4    11.0     255.    365.    214.  **
** 8/22/79    1600   29.3     8.4    11.1     271.    388.    228.  **
** 8/22/79    1700   29.3     8.6    10.8     285.    415.    244.  **
** 8/22/79    1800   28.1     9.1    10.3     286.    434.    255.  **
** 8/22/79    1900   26.4     8.8    10.6     269.    398.    234.  **
** 8/22/79    2000   24.3     9.1    10.3     258.    391.    230.  **
** 8/22/79    2100   24.3     9.3    10.1     252.    389.    228.  **
** 8/22/79    2200   23.4     9.4    10.0     237.    369.    217.  **
** 8/22/79    2300   22.0     9.8     9.6     222.    358.    210.  **
** 8/22/79    2400   19.6    10.7     8.5     200.    351.    206.  **
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**                      HOURLY DATA                          **
**               DRY STACK GAS CONCENTRATION                 **
**                                                           **
**                          O2      CO2     NO     NO     NO **
**                  LOAD   VOL%    VOL%   PPMV   PPMV   NG/J **
**   DATE     TIME  MWTH   MEAS    MEAS   MEAS   3%O2        **
***************************************************************
** 8/23/79     100  18.2   10.5     8.7   198.   341.   200.  **
** 8/23/79     200  16.2   10.7     8.4   195.   342.   201.  **
** 8/23/79     300  16.7   10.9     8.1   193.   345.   203.  **
** 8/23/79     400  16.1   11.1     7.9   189.   345.   203.  **
** 8/23/79     500  16.1   11.3     7.7   178.   332.   195.  **
** 8/23/79     600  16.4   11.3     7.8   179.   334.   196.  **
** 8/23/79     700  19.3   10.7     8.5   196.   344.   202.  **
** 8/23/79     800  19.6   10.7     8.6   202.   354.   208.  **
** 8/23/79     900  22.3    9.7     9.7   235.   376.   221.  **
** 8/23/79    1000  24.3    9.2    10.4   238.   364.   214.  **
** 8/23/79    1100  27.2    8.9    10.8   236.   352.   207.  **
** 8/23/79    1200  27.5     .0      .0     0.     0.     0.  **
** 8/23/79    1300  25.2     .0      .0     0.     0.     0.  **
** 8/23/79    1400  27.5    9.3    10.4   236.   364.   214.  **
** 8/23/79    1500  26.4     .0      .0     0.     0.     0.  **
** 8/23/79    1600  25.2     .0      .0     0.     0.     0.  **
** 8/23/79    1700  24.9     .0      .0     0.     0.     0.  **
** 8/23/79    1800  23.4     .0      .0     0.     0.     0.  **
** 8/23/79    1900  22.9     .0      .0     0.     0.     0.  **
** 8/23/79    2000  21.4     .0      .0     0.     0.     0.  **
** 8/23/79    2100  21.7     .0      .0     0.     0.     0.  **
** 8/23/79    2200  20.5     .0      .0     0.     0.     0.  **
** 8/23/79    2300  20.5     .0      .0     0.     0.     0.  **
** 8/23/79    2400  19.3     .0      .0     0.     0.     0.  **
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**                                                                       **
**                          HUURLY DATA                                  **
**                  DRY STACK GAS CONCENTRATION                          **
**                                                                       **
**                              O2       CO2      NU       NU       NO   **
**                     LOAD    VOL%     VOL%     PPMV     PPMV     NG/J  **
**   DATE      TIME    MWTH    MEAS     MEAS     MEAS     3%O2           **
***************************************************************************
** 8/24/79      100    17.6      .0       .0       0.       0.       0.  **
** 8/24/79      200    16.7      .0       .0       0.       0.       0.  **
** 8/24/79      300    17.6      .0       .0       0.       0.       0.  **
** 8/24/79      400    18.2      .0       .0       0.       0.       0.  **
** 8/24/79      500    18.2      .0       .0       0.       0.       0.  **
** 8/24/79      600    17.6      .0       .0       0.       0.       0.  **
** 8/24/79      700    18.2      .0       .0       0.       0.       0.  **
** 8/24/79      800    19.0      .0       .0       0.       0.       0.  **
** 8/24/79      900    22.0      .0       .0       0.       0.       0.  **
** 8/24/79     1000    24.3      .0       .0       0.       0.       0.  **
** 8/24/79     1100    26.4      .0       .0       0.       0.       0.  **
** 8/24/79     1200    27.0     9.0     10.5     227.     341.     200.  **
** 8/24/79     1300    27.5     8.9     10.8     239.     357.     209.  **
** 8/24/79     1400    27.8     8.8     10.9     224.     331.     195.  **
** 8/24/79     1500    25.2     9.0     10.7     237.     356.     209.  **
** 8/24/79     1600    24.9     9.3     10.4     234.     361.     212.  **
** 8/24/79     1700    24.0     9.5     10.1     231.     363.     213.  **
** 8/24/79     1800    22.6     9.9      9.7     223.     363.     213.  **
** 8/24/79     1900    21.4    10.5      9.2     215.     370.     217.  **
** 8/24/79     2000    20.5    10.5      9.2     214.     368.     216.  **
** 8/24/79     2100    20.5    10.4      9.4     210.     358.     210.  **
** 8/24/79     2200    20.5    10.4      9.3     212.     361.     212.  **
** 8/24/79     2300    20.2    10.5      9.2     209.     360.     211.  **
** 8/24/79     2400    17.6    11.4      8.2     195.     307.     216.  **
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**                                                               **
**                        HOURLY DATA                            **
**              DRY STACK GAS CONCENTRATION                      **
**                                                               **
**                            O2      CO2     NO      NO         **
**                    LOAD    VOL%    VOL%    PPMV    PPMV  NO   **
**   DATE     TIME    MWTH    MEAS    MEAS    MEAS    3%O2  NG/J **
*******************************************************************
** 8/25/79     100    20.5    10.4     9.3    218.    372.  218. **
** 8/25/79     200    19.0    10.8     8.9    204.    362.  212. **
** 8/25/79     300    17.6    11.0     8.6    197.    356.  209. **
** 8/25/79     400    17.6    11.1     8.5    201.    367.  216. **
** 8/25/79     500    17.6    11.1     8.5    198.    362.  212. **
** 8/25/79     600    16.7    11.3     8.2    204.    380.  223. **
** 8/25/79     700    17.3    11.0     8.7    204.    369.  217. **
** 8/25/79     800    16.7    11.2     8.4    195.    360.  211. **
** 8/25/79     900    20.5    10.3     9.4    219.    370.  217. **
** 8/25/79    1000    20.5    10.2     9.6    222.    371.  218. **
** 8/25/79    1100    22.3     9.4    10.1    224.    349.  205. **
** 8/25/79    1200    23.4     9.4    10.1    220.    342.  201. **
** 8/25/79    1300    23.4     9.4    10.1    220.    342.  201. **
** 8/25/79    1400    22.6     9.4     9.8    198.    308.  181. **
** 8/25/79    1500    21.4    10.0     9.4    206.    338.  199. **
** 8/25/79    1600    19.9    10.2     9.2    205.    343.  201. **
** 8/25/79    1700    20.2    10.2     9.3    209.    350.  205. **
** 8/25/79    1800    19.6    10.4     9.1    212.    361.  212. **
** 8/25/79    1900    19.0    10.6     8.9    218.    379.  222. **
** 8/25/79    2000    18.8    10.7     8.8    218.    383.  225. **
** 8/25/79    2100    19.6    10.5     9.0    212.    365.  214. **
** 8/25/79    2200    19.0    10.5     9.1    211.    363.  213. **
** 8/25/79    2300    17.6    11.0     8.4    189.    342.  201. **
** 8/25/79    2400    17.6    10.8     8.5    183.    324.  190. **
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HOURLY DATA
DRY STACK GAS CONCENTRATION

DATE	TIME	LOAD MWTH	O2 VOL% MEAS	CO2 VOL% MEAS	NO PPMV MEAS	NO PPMV 3%O2	NO NG/J
8/26/79	100	17.9	10.5	8.7	183.	315.	185.
8/26/79	200	16.7	11.0	8.1	173.	313.	184.
8/26/79	300	15.8	11.2	7.8	170.	314.	184.
8/26/79	400	16.4	11.0	8.0	174.	315.	185.
8/26/79	500	16.7	11.0	7.9	172.	311.	183.
8/26/79	600	16.4	11.0	7.9	181.	327.	192.
8/26/79	700	18.2	10.8	8.4	195.	346.	203.
8/26/79	800	17.6	10.8	8.5	197.	349.	205.
8/26/79	900	17.3	10.6	8.4	199.	353.	207.
8/26/79	1000	18.8	10.5	8.8	201.	346.	203.
8/26/79	1100	19.0	10.4	9.1	201.	343.	201.
8/26/79	1200	18.5	10.6	8.8	196.	341.	200.
8/26/79	1300	19.0	10.5	9.0	200.	344.	202.
8/26/79	1400	18.8	10.7	8.9	185.	325.	191.
8/26/79	1500	18.2	10.9	8.6	180.	322.	189.
8/26/79	1600	19.6	10.4	8.7	196.	334.	196.
8/26/79	1700	19.9	10.3	9.1	197.	333.	195.
8/26/79	1800	18.5	10.2	9.2	199.	333.	195.
8/26/79	1900	19.0	10.3	9.1	201.	339.	199.
8/26/79	2000	18.8	10.4	9.0	205.	349.	205.
8/26/79	2100	20.5	10.1	9.5	214.	355.	208.
8/26/79	2200	21.4	9.9	9.8	233.	379.	223.
8/26/79	2300	20.2	10.5	9.2	223.	384.	225.
8/26/79	2400	18.2	11.0	8.5	206.	372.	219.

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**                           HOURLY DATA                            **
**                   DRY STACK GAS CONCENTRATION                    **
**                                                                  **
**                            O2      CO2      NO      NO      NO   **
**                    LOAD    VOL%    VOL%    PPMV    PPMV    NG/J  **
**    DATE     TIME   MWTH    MEAS    MEAS    MEAS    3%O2          **
**********************************************************************
** 8/27/79      100   18.8    10.7     8.9    217.    381.    224.  **
** 8/27/79      200   17.3    11.1     8.5    204.    373.    219.  **
** 8/27/79      300   16.7    11.3     8.3    202.    377.    221.  **
** 8/27/79      400   16.4    11.3     8.1    196.    365.    215.  **
** 8/27/79      500   16.7    11.3     8.0    190.    354.    208.  **
** 8/27/79      600   17.6    11.2     8.1    196.    362.    212.  **
** 8/27/79      700   18.5    10.9     8.5    202.    362.    212.  **
** 8/27/79      800   19.0    11.0     8.5    202.    365.    214.  **
** 8/27/79      900   22.0    10.0     9.8    229.    376.    221.  **
** 8/27/79     1000   26.1     9.3    10.5    242.    373.    219.  **
** 8/27/79     1100   27.2     9.0    10.8    249.    375.    220.  **
** 8/27/79     1200   29.0     8.5    11.0    252.    364.    214.  **
** 8/27/79     1300   29.0     8.5    11.2    247.    357.    209.  **
** 8/27/79     1400   29.3     8.5    11.1    241.    348.    204.  **
** 8/27/79     1500   28.4     8.5    11.1    247.    357.    209.  **
** 8/27/79     1600   28.4     8.4    11.1    261.    374.    219.  **
** 8/27/79     1700   27.5     8.8    10.7    273.    404.    237.  **
** 8/27/79     1800   27.0     8.9    10.5    267.    398.    234.  **
** 8/27/79     1900   25.5     9.3    10.3    271.    418.    246.  **
** 8/27/79     2000   24.3     9.4    10.0    256.    398.    234.  **
** 8/27/79     2100   24.9     9.3    10.1    236.    364.    214.  **
** 8/27/79     2200   22.0    10.1     9.2    232.    385.    226.  **
** 8/27/79     2300   20.2    10.4     8.8    226.    385.    226.  **
** 8/27/79     2400   16.5    10.9     8.2    201.    360.    211.  **
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**                                                                          **
**                              HOURLY DATA                                 **
**                      DRY STACK GAS CONCENTRATION                         **
**                                                                          **
**                             O2      CO2      NO       NO                 **
**                     LOAD   VOL%     VOL%     PPMV     PPMV     NO        **
**    DATE     TIME    MWTH   MEAS     MEAS     MEAS     3%O2     NG/J      **
******************************************************************************
**  8/28/79     100    18.5   10.7      8.4     209.     367.     215.      **
**  8/28/79     200    18.2   10.8      8.4     202.     358.     210.      **
**  8/28/79     300    18.5   10.6      8.6     199.     346.     203.      **
**  8/28/79     400    18.2   10.7      8.6     200.     351.     206.      **
**  8/28/79     500    18.8   10.6      8.6     191.     332.     195.      **
**  8/28/79     600    18.2   10.6      8.5     210.     365.     214.      **
**  8/28/79     700    20.2   10.4      8.8     214.     365.     214.      **
**  8/28/79     800    20.5   10.1      9.2     205.     340.     199.      **
**  8/28/79     900    23.4    9.3     10.0     218.     336.     198.      **
**  8/28/79    1000    26.1    8.9     10.5     224.     334.     196.      **
**  8/28/79    1100    27.8    8.4     11.0     237.     339.     199.      **
**  8/28/79    1200    31.1    8.1     11.3     238.     333.     195.      **
**  8/28/79    1300    29.3    8.6     10.9     250.     364.     214.      **
**  8/28/79    1400    29.6    8.6     10.7     228.     332.     195.      **
**  8/28/79    1500    32.8    7.7     11.6     232.     315.     185.      **
**  8/28/79    1600    31.4    8.0     11.4     239.     332.     195.      **
**  8/28/79    1700    30.5    8.2     11.2     262.     369.     217.      **
**  8/28/79    1800    27.2    8.6     10.8     250.     364.     214.      **
**  8/28/79    1900    24.6    8.9     10.3     244.     364.     214.      **
**  8/28/79    2000    23.4    8.8     10.0     243.     359.     211.      **
**  8/28/79    2100    24.6    8.3     10.6     225.     320.     188.      **
**  8/28/79    2200    24.0    9.2     10.0     237.     363.     213.      **
**  8/28/79    2300    22.6    9.6      9.7     227.     360.     211.      **
**  8/28/79    2400    19.9   10.6      8.6     211.     367.     215.      **
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**                                                                           **
**                          HOURLY DATA                                      **
**                  DRY STACK GAS CONCENTRATION                              **
**                                                                           **
**                            O2       CO2       NO        NO        NO      **
**                   LOAD     VOL%     VOL%      PPMV      PPMV      NG/J    **
**    DATE    TIME   MWTH     MEAS     MEAS      MEAS      3%O2              **
*******************************************************************************
** 8/29/79     100   16.5     10.8      8.6      214.      379.      223.    **
** 8/29/79     200   16.7     11.0      8.2      205.      371.      218.    **
** 8/29/79     300   16.4     11.2      8.0      199.      367.      216.    **
** 8/29/79     400   16.1     11.2      8.0      202.      373.      219.    **
** 8/29/79     500   18.2     10.7      8.7      212.      372.      218.    **
** 8/29/79     600   18.8     10.5      8.9      228.      392.      230.    **
** 8/29/79     700   20.5     10.2      9.2      226.      378.      222.    **
** 8/29/79     800   22.0      9.7      9.7      231.      369.      217.    **
** 8/29/79     900   26.4      9.0     10.5      254.      382.      224.    **
** 8/29/79    1000   30.2      8.1     11.3      271.      379.      223.    **
** 8/29/79    1100   32.8      7.5     12.1      272.      363.      213.    **
** 8/29/79    1200   34.3      7.0     12.5      252.      325.      191.    **
** 8/29/79    1300   34.3      7.2     12.3      251.      328.      193.    **
** 8/29/79    1400   34.6      6.9     12.5      256.      327.      192.    **
** 8/29/79    1500   33.7      7.3     12.2      255.      336.      197.    **
** 8/29/79    1600   31.4      8.0     11.7      279.      387.      227.    **
** 8/29/79    1700   30.8      8.4     11.4      278.      398.      234.    **
** 8/29/79    1800   31.1      8.3     11.5      282.      401.      235.    **
** 8/29/79    1900   29.3      8.9     11.0      286.      427.      250.    **
** 8/29/79    2000   27.2      8.8     11.1      268.      396.      233.    **
** 8/29/79    2100   27.8      8.4     11.3      254.      364.      214.    **
** 8/29/79    2200   25.5      8.9     10.7      248.      370.      217.    **
** 8/29/79    2300   24.3      9.3     10.3      242.      373.      219.    **
** 8/29/79    2400   19.9     10.6      8.9      223.      388.      228.    **
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**                              HOURLY DATA                                 **
**                      DRY STACK GAS CONCENTRATION                         **
**                                                                          **
**                               O2      CO2      NO      NO      NO        **
**                       LOAD    VOL%    VOL%     PPMV    PPMV    NG/J      **
**    DATE      TIME     MWTH    MEAS    MEAS     MEAS    3%O2              **
******************************************************************************
** 8/30/79       100     18.5    10.6     8.8     221.    392.    230.      **
** 8/30/79       200     16.7    11.0     8.4     204.    369.    217.      **
** 8/30/79       300     16.4    11.0     8.4     204.    369.    217.      **
** 8/30/79       400     16.4    11.2     8.2     200.    369.    217.      **
** 8/30/79       500     16.7    11.1     8.3     186.    340.    199.      **
** 8/30/79       600     17.0    11.0     8.4     192.    347.    204.      **
** 8/30/79       700     20.2    10.2     9.3     206.    345.    202.      **
** 8/30/79       800     22.3    10.0     9.6     196.    322.    189.      **
** 8/30/79       900     24.9     9.3    10.4     215.    332.    195.      **
** 8/30/79      1000     27.0     6.9    10.8     223.    333.    195.      **
** 8/30/79      1100     29.0     8.8    11.0     236.    349.    205.      **
** 8/30/79      1200     29.3     8.6    10.9     248.    361.    212.      **
** 8/30/79      1300     29.6     6.6    11.2     253.    368.    216.      **
** 8/30/79      1400     30.8     8.2    11.4     252.    355.    209.      **
** 8/30/79      1500     30.8     8.2    11.3     266.    375.    220.      **
** 8/30/79      1600     30.5     8.2    11.2     268.    378.    222.      **
** 8/30/79      1700     30.8     8.1    11.4     286.    400.    235.      **
** 8/30/79      1800     30.5     8.3    11.2     280.    398.    234.      **
** 8/30/79      1900     27.8     8.6    10.9     272.    396.    232.      **
** 8/30/79      2000     27.5     8.8    10.7     264.    391.    229.      **
** 8/30/79      2100     27.8     8.6    10.9     246.    358.    210.      **
** 8/30/79      2200     25.8     9.3    10.2     249.    384.    226.      **
** 8/30/79      2300     24.0     9.4    10.1     248.    386.    227.      **
** 8/30/79      2400     20.2    10.3     9.1     234.    395.    232.      **
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**                                                                         **
**                             HOURLY DATA                                 **
**                    DRY STACK GAS CONCENTRATION                          **
**                                                                         **
**                               O2       CO2      NO       NO      NO     **
**                      LOAD     VOL%     VOL%     PPMV     PPMV    NG/J   **
**   DATE       TIME    MWTH     MEAS     MEAS     MEAS     3%O2           **
*****************************************************************************
** 8/31/79       100    19.9     10.3      9.1     245.     414.    243.   **
** 8/31/79       200    18.8     10.8      8.7     238.     422.    246.   **
** 8/31/79       300    17.6     11.1      8.2     225.     411.    241.   **
** 8/31/79       400    17.6     10.9      8.5     216.     387.    227.   **
** 8/31/79       500    16.2     11.0      8.4     205.     371.    218.   **
** 8/31/79       600    16.5     10.8      8.7     221.     392.    230.   **
** 8/31/79       700    22.0      9.9      9.7     246.     400.    235.   **
** 8/31/79       800    23.4      9.6     10.2     251.     398.    233.   **
** 8/31/79       900    27.8      8.6     10.9     270.     393.    231.   **
** 8/31/79      1000    33.7      6.9     12.3     232.     297.    174.   **
** 8/31/79      1100    34.0      7.2     12.2     246.     321.    189.   **
** 8/31/79      1200    32.8      7.4     12.0     249.     330.    194.   **
** 8/31/79      1300    32.8      6.9     12.2     253.     323.    190.   **
** 8/31/79      1400    31.9      7.3     11.8     249.     328.    192.   **
** 8/31/79      1500    30.8      7.8     11.2     264.     361.    212.   **
** 8/31/79      1600    32.2      7.1     12.0     265.     344.    202.   **
** 8/31/79      1700    31.6      7.3     11.9     268.     353.    207.   **
** 8/31/79      1800    30.2      7.8     11.3     263.     359.    211.   **
** 8/31/79      1900    24.3      7.6     11.3     255.     348.    205.   **
** 8/31/79      2000    27.5      8.0     11.1     222.     308.    181.   **
** 8/31/79      2100    29.3      7.7     11.3     188.     255.    150.   **
** 8/31/79      2200    28.1      8.4     11.1     212.     304.    178.   **
** 8/31/79      2300    29.0      8.5     11.2     238.     344.    202.   **
** 8/31/79      2400    26.1      9.0     10.8     224.     337.    198.   **
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**                                                           **
**                      HOURLY DATA                          **
**               DRY STACK GAS CONCENTRATION                 **
**                                                           **
**                         O2      CO2     NO     NO     NO  **
**                  LOAD   VOL%    VOL%    PPMV   PPMV   NG/J **
**   DATE    TIME   MWTH   MEAS    MEAS    MEAS   3%O2        **
***************************************************************
** 9/ 1/79    100   24.9    9.2    10.7    220.   337.   198.  **
** 9/ 1/79    200   22.9    9.8    10.1    200.   323.   189.  **
** 9/ 1/79    300   20.5   10.3     9.4    182.   307.   180.  **
** 9/ 1/79    400   19.6   10.6     9.2    175.   304.   179.  **
** 9/ 1/79    500   18.6   11.3     8.4    160.   298.   175.  **
** 9/ 1/79    600   18.5   11.0     8.8    159.   287.   169.  **
** 9/ 1/79    700   20.2   10.7     9.1    166.   291.   171.  **
** 9/ 1/79    800   20.2   10.5     9.3    171.   294.   173.  **
** 9/ 1/79    900   20.5   10.5     9.5    170.   293.   172.  **
** 9/ 1/79   1000   22.9    9.7    10.2    195.   312.   183.  **
** 9/ 1/79   1100   26.1    9.2    10.8    214.   327.   192.  **
** 9/ 1/79   1200   27.5    8.6    11.2    223.   325.   191.  **
** 9/ 1/79   1300   27.5    8.7    11.1    252.   370.   217.  **
** 9/ 1/79   1400   27.5    8.2    11.2    269.   379.   223.  **
** 9/ 1/79   1500   25.8    8.7    10.8    274.   402.   236.  **
** 9/ 1/79   1600   24.9    8.9    10.6    277.   413.   243.  **
** 9/ 1/79   1700   24.6    9.0    10.5    269.   405.   238.  **
** 9/ 1/79   1800   24.3    9.2    10.2    257.   393.   231.  **
** 9/ 1/79   1900   22.9    9.5     9.8    241.   378.   222.  **
** 9/ 1/79   2000   21.1    9.8     9.4    232.   374.   220.  **
** 9/ 1/79   2100   23.1    9.3    10.1    229.   353.   207.  **
** 9/ 1/79   2200   21.1    9.7     9.7    236.   377.   221.  **
** 9/ 1/79   2300   19.3   10.2     9.2    225.   376.   221.  **
** 9/ 1/79   2400   19.0   10.3     9.2    221.   373.   219.  **
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**                          HOURLY DATA                          **
**                 DRY STACK GAS CONCENTRATION                   **
**                                                               **
**                           O2      CO2     NO      NO     NO   **
**                   LOAD   VOL%    VOL%    PPMV    PPMV   NG/J  **
**   DATE     TIME   MWTH   MEAS    MEAS    MEAS    3%O2         **
*******************************************************************
** 9/ 2/79     100   19.3   10.0     9.3    218.    358.   210.  **
** 9/ 2/79     200   18.2   10.5     8.8    206.    355.   208.  **
** 9/ 2/79     300   16.7   10.6     8.6    199.    346.   203.  **
** 9/ 2/79     400   17.6   10.2     9.0    205.    343.   201.  **
** 9/ 2/79     500   18.2   10.3     9.0    202.    341.   200.  **
** 9/ 2/79     600   17.6   10.5     8.9    208.    358.   210.  **
** 9/ 2/79     700   17.6   10.4     9.0    209.    356.   209.  **
** 9/ 2/79     800   18.5   10.3     9.2    208.    351.   206.  **
** 9/ 2/79     900   17.3   10.7     8.6    185.    325.   191.  **
** 9/ 2/79    1000   17.6   10.6     8.8    194.    337.   198.  **
** 9/ 2/79    1100   18.8   10.3     9.1    201.    339.   199.  **
** 9/ 2/79    1200   20.2   10.0     9.5    211.    347.   203.  **
** 9/ 2/79    1300   21.7    9.7     9.8    217.    347.   204.  **
** 9/ 2/79    1400   21.7    9.9     9.7    209.    340.   200.  **
** 9/ 2/79    1500   19.0   10.6     9.2    210.    365.   214.  **
** 9/ 2/79    1600   18.8   10.6     9.1    208.    361.   212.  **
** 9/ 2/79    1700   18.5   10.7     9.0    211.    370.   217.  **
** 9/ 2/79    1800   18.2   10.9     8.8    207.    371.   218.  **
** 9/ 2/79    1900   17.9   10.9     8.8    209.    374.   220.  **
** 9/ 2/79    2000   17.3   11.0     8.8    209.    378.   222.  **
** 9/ 2/79    2100   19.0   10.5     9.4    212.    365.   214.  **
** 9/ 2/79    2200   18.8   10.5     9.4    220.    379.   222.  **
** 9/ 2/79    2300   18.2   10.8     9.0    202.    358.   210.  **
** 9/ 2/79    2400   17.6   10.8     8.9    198.    351.   206.  **
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**                                                                      **
**                           HOURLY DATA                                **
**                  DRY STACK GAS CONCENTRATION                         **
**                                                                      **
**                                O2       CO2      NO       NO         **
**                       LOAD    VOL%     VOL%     PPMV     PPMV    NO  **
**   DATE        TIME    MWTH    MEAS     MEAS     MEAS     3%O2   NG/J **
**************************************************************************
** 9/ 3/79        100    18.2    10.6      9.2     200.     348.   204. **
** 9/ 3/79        200    17.0    10.9      8.9     191.     342.   201. **
** 9/ 3/79        300    18.8    10.4      9.4     199.     339.   199. **
** 9/ 3/79        400    18.5    10.4      9.4     199.     339.   199. **
** 9/ 3/79        500    18.8    10.5      9.3     193.     332.   195. **
** 9/ 3/79        600    18.5    10.6      9.3     207.     360.   211. **
** 9/ 3/79        700    18.5    10.5      9.3     206.     355.   208. **
** 9/ 3/79        800    18.8    10.5      9.3     199.     343.   201. **
** 9/ 3/79        900    20.2    10.3      9.6     209.     353.   207. **
** 9/ 3/79       1000    18.8    10.6      9.3     208.     361.   212. **
** 9/ 3/79       1100    18.5    10.6      9.2     208.     361.   212. **
** 9/ 3/79       1200    19.0    10.4      9.5     216.     368.   216. **
** 9/ 3/79       1300    19.0    10.3       .0     217.     366.   215. **
** 9/ 3/79       1400    19.9    10.2       .0     202.     338.   198. **
** 9/ 3/79       1500    18.5      .0       .0       0.       0.     0. **
** 9/ 3/79       1600    16.5    10.6      9.0     190.     330.   194. **
** 9/ 3/79       1700    18.8    10.1      9.7     183.     303.   178. **
** 9/ 3/79       1800    18.8    10.1      9.7     183.     303.   178. **
** 9/ 3/79       1900    18.8    10.0      9.8     184.     302.   177. **
** 9/ 3/79       2000    19.9    10.0      9.9     184.     302.   177. **
** 9/ 3/79       2100    22.0     9.3     10.6     193.     298.   175. **
** 9/ 3/79       2200    21.7     9.4     10.5     195.     304.   178. **
** 9/ 3/79       2300    19.9     9.9      9.9     185.     301.   177. **
** 9/ 3/79       2400    19.0      .0       .0       0.       0.     0. **
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****************************************************************
**                        HOURLY DATA                         **
**               DRY STACK GAS CONCENTRATION                  **
**                                                            **
**                          O2      CO2     NO     NO     NO  **
**                    LOAD  VOL%    VOL%    PPMV   PPMV  NG/J **
**   DATE      TIME   MWTH  MEAS    MEAS    MEAS   3%O2       **
****************************************************************
** 9/ 4/79      100   19.0  10.0     9.7    189.   310.  182. **
** 9/ 4/79      200   16.8  10.0     9.7    192.   315.  185. **
** 9/ 4/79      300   16.5  10.0     9.6    192.   315.  185. **
** 9/ 4/79      400   17.9  10.3     9.2    181.   306.  179. **
** 9/ 4/79      500   18.2  10.3     9.2    185.   312.  183. **
** 9/ 4/79      600   17.6  10.5     9.0    185.   318.  187. **
** 9/ 4/79      700   17.9  10.4     9.0    193.   329.  193. **
** 9/ 4/79      800   19.9  10.2     9.3    196.   328.  193. **
** 9/ 4/79      900   26.4   9.5    10.2    206.   323.  190. **
** 9/ 4/79     1000   29.3   8.9    10.9    235.   351.  206. **
** 9/ 4/79     1100   33.7   8.2    11.1    254.   358.  210. **
** 9/ 4/79     1200   33.7   7.9    11.6    245.   337.  198. **
** 9/ 4/79     1300   34.0   7.4    12.4    253.   335.  197. **
** 9/ 4/79     1400   34.9   7.2    12.5    252.   329.  193. **
** 9/ 4/79     1500   35.2   7.0    12.8    294.   379.  222. **
** 9/ 4/79     1600   35.2   7.0    12.8    298.   384.  225. **
** 9/ 4/79     1700   35.7   6.7    13.0    293.   369.  217. **
** 9/ 4/79     1800   33.7   7.1    12.7    283.   367.  216. **
** 9/ 4/79     1900   30.8   8.3    11.6    289.   411.  241. **
** 9/ 4/79     2000   29.3   8.9    11.0    276.   412.  242. **
** 9/ 4/79     2100   32.2   8.0    11.8    266.   369.  217. **
** 9/ 4/79     2200   30.8   8.6    11.2    266.   387.  227. **
** 9/ 4/79     2300   27.8   9.0    10.6    262.   394.  231. **
** 9/ 4/79     2400   22.0  10.0     9.4    236.   388.  228. **
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**                          HOURLY DATA                     **
**                 DRY STACK GAS CONCENTRATION              **
**                                                          **
**                           O2      CO2     NO     NO      **
**                   LOAD   VOL%    VOL%    PPMV   PPMV   NO       **
**  DATE      TIME   MWTH   MEAS    MEAS    MEAS   3%O2   NG/J     **
**************************************************************
** 9/ 5/79     100   22.0    9.7     9.8    245.   392.   230.    **
** 9/ 5/79     200   19.9   10.4     9.0    230.   392.   230.    **
** 9/ 5/79     300   16.7   11.2     8.0    206.   380.   223.    **
** 9/ 5/79     400   18.2   10.9     8.4    213.   381.   224.    **
** 9/ 5/79     500   19.6   10.5     8.9    204.   351.   206.    **
** 9/ 5/79     600   19.9   10.4     9.0    193.   329.   193.    **
** 9/ 5/79     700   22.0    9.9     9.6    207.   337.   198.    **
** 9/ 5/79     800   25.5    9.4    10.2    219.   341.   200.    **
** 9/ 5/79     900   27.8    8.9    10.9    251.   374.   220.    **
** 9/ 5/79    1000   32.2    8.0    11.7    250.   347.   204.    **
** 9/ 5/79    1100   32.2    7.7    12.0    250.   339.   199.    **
** 9/ 5/79    1200   32.5    7.2    12.1    253.   331.   194.    **
** 9/ 5/79    1300   31.1    7.3    11.8    262.   345.   202.    **
** 9/ 5/79    1400   30.8    7.7    11.4    272.   369.   217.    **
** 9/ 5/79    1500   27.2    8.4    10.7    272.   390.   229.    **
** 9/ 5/79    1600   30.5    8.0    11.5    292.   405.   238.    **
** 9/ 5/79    1700   30.8    8.1    11.5    286.   400.   235.    **
** 9/ 5/79    1800   29.0    8.5    11.1    260.   375.   220.    **
** 9/ 5/79    1900   28.4    8.5    11.1    260.   375.   220.    **
** 9/ 5/79    2000   26.4    8.9    10.8    248.   370.   217.    **
** 9/ 5/79    2100   26.1    8.4    11.3    226.   324.   190.    **
** 9/ 5/79    2200   24.6    9.4    10.3    229.   356.   209.    **
** 9/ 5/79    2300   22.6    9.9     9.5    216.   351.   206.    **
** 9/ 5/79    2400   19.3   11.1     8.4    199.   363.   213.    **
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HUURLY DATA
DRY STACK GAS CONCENTRATION

DATE	TIME	LOAD MWTH	O2 VOL% MEAS	CO2 VOL% MEAS	NO PPMV MEAS	NO PPMV 3%O2	NO NG/J
9/ 6/79	100	20.5	10.4	9.2	220.	375.	220.
9/ 6/79	200	19.6	10.4	9.3	224.	382.	224.
9/ 6/79	300	19.3	10.6	9.1	212.	368.	216.
9/ 6/79	400	18.8	10.7	8.9	199.	349.	205.
9/ 6/79	500	19.3	10.6	9.1	185.	322.	189.
9/ 6/79	600	19.3	10.6	9.1	197.	342.	201.
9/ 6/79	700	19.9	10.6	9.1	194.	337.	198.
9/ 6/79	800	22.0	10.3	9.5	198.	334.	196.
9/ 6/79	900	24.6	9.4	9.4	227.	353.	207.
9/ 6/79	1000	27.5	9.0	10.6	234.	352.	207.
9/ 6/79	1100	27.8	6.9	10.8	238.	355.	208.
9/ 6/79	1200	26.4	8.8	10.9	236.	349.	205.
9/ 6/79	1300	28.1	8.8	11.0	242.	358.	210.
9/ 6/79	1400	27.8	8.8	10.9	246.	364.	214.
9/ 6/79	1500	27.5	8.9	10.9	251.	374.	220.
9/ 6/79	1600	27.2	8.9	10.8	247.	368.	216.
9/ 6/79	1700	26.7	8.9	10.7	247.	368.	216.
9/ 6/79	1800	25.2	9.1	10.4	245.	372.	218.
9/ 6/79	1900	23.4	9.4	10.0	245.	381.	224.
9/ 6/79	2000	22.6	9.5	9.9	233.	366.	215.
9/ 6/79	2100	24.9	9.1	10.4	210.	319.	187.
9/ 6/79	2200	22.3	9.8	9.5	210.	339.	199.
9/ 6/79	2300	21.4	9.9	9.5	211.	343.	202.
9/ 6/79	2400	17.3	10.8	8.2	193.	342.	201.

HOURLY DATA
DRY STACK GAS CONCENTRATION

DATE	TIME	LOAD MWTH	O2 VOL% MEAS	CO2 VOL% MEAS	NO PPMV MEAS	NO PPMV 3%O2	NO NG/J
9/ 7/79	100	18.8	10.1	9.2	238.	394.	232.
9/ 7/79	200	18.5	10.4	8.8	228.	389.	228.
9/ 7/79	300	16.7	10.7	8.4	215.	377.	222.
9/ 7/79	400	16.7	10.7	8.4	202.	354.	208.
9/ 7/79	500	18.2	10.4	8.7	197.	336.	197.
9/ 7/79	600	18.5	10.4	8.8	209.	356.	209.
9/ 7/79	700	19.3	10.3	8.9	205.	346.	203.
9/ 7/79	800	21.7	9.9	9.5	217.	353.	207.
9/ 7/79	900	24.3	9.2	10.0	228.	349.	205.
9/ 7/79	1000	26.1	9.0	10.6	235.	353.	208.
9/ 7/79	1100	27.5	8.8	10.8	237.	351.	206.
9/ 7/79	1200	28.4	8.6	11.0	218.	317.	186.
9/ 7/79	1300	26.4	8.5	11.1	221.	319.	187.
9/ 7/79	1400	27.8	8.7	10.9	235.	345.	202.
9/ 7/79	1500	27.5	8.8	10.7	243.	359.	211.
9/ 7/79	1600	25.2	9.3	10.3	237.	366.	215.
9/ 7/79	1700	24.3	9.2	10.4	236.	361.	212.
9/ 7/79	1800	22.9	9.5	10.0	238.	374.	219.
9/ 7/79	1900	21.7	9.8	9.7	232.	374.	220.
9/ 7/79	2000	20.5	10.0	9.4	230.	378.	222.
9/ 7/79	2100	22.0	9.8	9.6	225.	363.	213.
9/ 7/79	2200	20.2	10.1	9.2	224.	371.	218.
9/ 7/79	2300	20.2	10.1	9.3	222.	368.	216.
9/ 7/79	2400	16.7	10.7	8.5	204.	358.	210.

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************************************************************************
**                            HOURLY DATA                             **
**                    DRY STACK GAS CONCENTRATION                     **
**                                                                    **
**                                O2     CO2      NO      NO      NO  **
**                        LOAD    VOL%    VOL%    PPMV    PPMV    NG/J  **
**    DATE      TIME      MWTH    MEAS    MEAS    MEAS    3%O2          **
************************************************************************
** 9/ 8/79       100  18.8    10.4     8.9    213.    363.    213.     **
** 9/ 8/79       200  19.0    10.3     9.0    221.    373.    219.     **
** 9/ 8/79       300  17.6    10.6     8.6    215.    374.    219.     **
** 9/ 8/79       400  17.6    10.6     8.5    211.    367.    215.     **
** 9/ 8/79       500  17.3    10.8     8.4    201.    356.    209.     **
** 9/ 8/79       600  17.0    10.8     8.3    207.    367.    215.     **
** 9/ 8/79       700  16.8    10.4     8.9    207.    353.    207.     **
** 9/ 8/79       800  18.5    10.6     8.7    199.    346.    203.     **
** 9/ 8/79       900  19.0    10.5     8.7    191.    329.    193.     **
** 9/ 8/79      1000  21.7     9.8     9.6    209.    337.    198.     **
** 9/ 8/79      1100  22.3     9.6     9.5    214.    339.    199.     **
** 9/ 8/79      1200  23.4     9.4    10.0    202.    314.    185.     **
** 9/ 8/79      1300  20.1     8.9    10.5    225.    336.    197.     **
** 9/ 8/79      1400  26.4     8.8    10.7    252.    373.    219.     **
** 9/ 8/79      1500  26.1     8.9    10.7    277.    413.    243.     **
** 9/ 8/79      1600  18.5    10.2     8.9    246.    412.    242.     **
** 9/ 8/79      1700  18.8    10.3     9.0    255.    431.    253.     **
** 9/ 8/79      1800  18.8    10.3     9.0    253.    427.    251.     **
** 9/ 8/79      1900  18.8    10.2     9.1    258.    432.    253.     **
** 9/ 8/79      2000  18.8    10.1     9.2    262.    434.    255.     **
** 9/ 8/79      2100  19.3    10.1     9.2    262.    434.    255.     **
** 9/ 8/79      2200  18.5    10.2     9.1    273.    457.    268.     **
** 9/ 8/79      2300  16.7    10.7     8.5    254.    446.    262.     **
** 9/ 8/79      2400  17.3    10.5     8.6    248.    427.    251.     **
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**                            HOURLY DATA                           **
**                   DRY STACK GAS CONCENTRATION                    **
**                                                                  **
**                             O2       CO2      NO      NO     NO  **
**                     LOAD   VOL%     VOL%     PPMV    PPMV   NG/J **
**   DATE      TIME    MWTH   MEAS     MEAS     MEAS    3%O2        **
**********************************************************************
** 9/ 9/79      100    17.6   10.3      8.9     244.    412.   242. **
** 9/ 9/79      200    18.2   10.3      8.9     247.    417.   245. **
** 9/ 9/79      300    17.6   10.4      8.8     247.    421.   247. **
** 9/ 9/79      400    17.3   10.6      8.6     242.    421.   247. **
** 9/ 9/79      500    17.0   10.7      8.4     232.    407.   239. **
** 9/ 9/79      600    16.4   10.7      8.3     235.    412.   242. **
** 9/ 9/79      700    17.6   10.5      8.6     238.    410.   241. **
** 9/ 9/79      800    18.8   10.2      9.0     247.    413.   243. **
** 9/ 9/79      900    17.6   10.5      8.6     237.    408.   239. **
** 9/ 9/79     1000    17.6   10.4      8.7     243.    414.   243. **
** 9/ 9/79     1100    18.8   10.1      9.0     250.    414.   243. **
** 9/ 9/79     1200    20.2   10.0      9.2     252.    414.   243. **
** 9/ 9/79     1300    19.0   10.2      9.2     240.    401.   236. **
** 9/ 9/79     1400    19.3   10.4      9.1     227.    387.   227. **
** 9/ 9/79     1500    18.2   10.5      8.9     236.    406.   238. **
** 9/ 9/79     1600    18.5   10.4      8.9     223.    380.   223. **
** 9/ 9/79     1700    18.5   10.3      9.1     228.    385.   226. **
** 9/ 9/79     1800    19.6   10.1      9.3     238.    394.   232. **
** 9/ 9/79     1900    20.2   10.0      9.5     257.    422.   248. **
** 9/ 9/79     2000    20.8    9.9      9.7     251.    408.   240. **
** 9/ 9/79     2100    24.6    9.0     10.6     262.    394.   231. **
** 9/ 9/79     2200    23.4    9.2     10.4     271.    415.   243. **
** 9/ 9/79     2300    21.7    9.7      9.9     259.    414.   243. **
** 9/ 9/79     2400    20.2   10.0      9.3     243.    399.   234. **
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**                         HOURLY DATA                          **
**                DRY STACK GAS CONCENTRATION                   **
**                                                              **
**                           O2      CO2      NO      NO      NO  **
**                   LOAD   VOL%    VOL%    PPMV    PPMV    NG/J  **
**   DATE    TIME    MWTH   MEAS    MEAS    MEAS    3%O2          **
*****************************************************************
** 9/10/79    100    19.6   10.5     8.8    227.    391.    229.  **
** 9/10/79    200    16.4   10.9     8.2    212.    379.    223.  **
** 9/10/79    300    17.9   10.5     8.7    219.    377.    221.  **
** 9/10/79    400    17.9   10.5     8.8    220.    379.    222.  **
** 9/10/79    500    17.6   10.6     8.8    217.    377.    221.  **
** 9/10/79    600    18.2   10.5     8.9    229.    394.    231.  **
** 9/10/79    700    20.2   10.2     9.3    242.    405.    238.  **
** 9/10/79    800    22.0    9.9     9.7    249.    405.    238.  **
** 9/10/79    900    25.5    8.5    11.1    277.    400.    235.  **
** 9/10/79   1000    27.8    8.4    11.1    268.    384.    225.  **
** 9/10/79   1100    29.6    8.4    11.1    256.    367.    215.  **
** 9/10/79   1200    30.8    7.9    11.5    229.    315.    185.  **
** 9/10/79   1300    28.1    8.5    11.1    230.    332.    195.  **
** 9/10/79   1400    27.8    8.5    11.0    247.    357.    209.  **
** 9/10/79   1500    27.2    8.5    10.9    259.    374.    220.  **
** 9/10/79   1600    27.8    8.7    10.9    260.    381.    224.  **
** 9/10/79   1700    27.8    8.4    11.1    252.    361.    212.  **
** 9/10/79   1800    27.5     .0      .0      0.      0.      0.  **
** 9/10/79   1900    25.8     .0      .0      0.      0.      0.  **
** 9/10/79   2000    25.2     .0      .0      0.      0.      0.  **
** 9/10/79   2100    26.4     .0      .0      0.      0.      0.  **
** 9/10/79   2200    22.9     .0      .0      0.      0.      0.  **
** 9/10/79   2300    21.4     .0      .0      0.      0.      0.  **
** 9/10/79   2400    19.0     .0      .0      0.      0.      0.  **
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**                                                                  **
**                            HOURLY DATA                           **
**                  DRY STACK GAS CONCENTRATION                     **
**                                                                  **
**                             O2       CO2      NO      NO         **
**                    LOAD    VOL%     VOL%     PPMV    PPMV    NO  **
**    DATE     TIME   MWTH    MEAS     MEAS     MEAS    3%O2   NG/J **
**********************************************************************
** 9/11/79      100   18.5      .0       .0       0.      0.     0. **
** 9/11/79      200   17.0      .0       .0       0.      0.     0. **
** 9/11/79      300   16.4      .0       .0       0.      0.     0. **
** 9/11/79      400   16.4      .0       .0       0.      0.     0. **
** 9/11/79      500   16.7      .0       .0       0.      0.     0. **
** 9/11/79      600   17.0      .0       .0       0.      0.     0. **
** 9/11/79      700   20.5      .0       .0       0.      0.     0. **
** 9/11/79      800   22.0     8.3     11.0     267.    379.   223. **
** 9/11/79      900   26.4     8.3     10.8     254.    361.   212. **
** 9/11/79     1000   27.0     8.3     10.9     253.    359.   211. **
** 9/11/79     1100   27.8     8.3     11.0     245.    348.   204. **
** 9/11/79     1200   29.3     8.0     11.4     240.    333.   196. **
** 9/11/79     1300   27.2     9.1     10.3     268.    407.   239. **
** 9/11/79     1400   27.2     9.0     10.3     276.    415.   244. **
** 9/11/79     1500   27.8     8.5     10.8     277.    400.   235. **
** 9/11/79     1600   27.5     8.5     10.8     277.    400.   235. **
** 9/11/79     1700   26.4     8.6     10.5     278.    405.   238. **
** 9/11/79     1800   25.2     8.8     10.5     274.    405.   238. **
** 9/11/79     1900   23.4     9.1     10.2     269.    408.   240. **
** 9/11/79     2000   22.3     9.2     10.0     266.    407.   239. **
** 9/11/79     2100   24.3     8.9     10.4     269.    401.   236. **
** 9/11/79     2200   21.7     9.3      9.8     228.    352.   207. **
** 9/11/79     2300   20.5     9.6      9.5     215.    341.   200. **
** 9/11/79     2400   19.3    10.6      8.3     218.    379.   222. **
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**                                                                     **
**                          HOURLY DATA                                **
**                   DRY STACK GAS CONCENTRATION                       **
**                                                                     **
**                                O2       CO2      NO       NO     NO  **
**                         LOAD   VOL%     VOL%     PPMV     PPMV   NG/J **
**   DATE         TIME     MWTH   MEAS     MEAS     MEAS     3%O2        **
*************************************************************************
** 9/12/79        100       .0    10.4      8.3     218.     372.   218.  **
** 9/12/79        200       .0    10.4      8.3     216.     368.   216.  **
** 9/12/79        300       .0    10.6      7.9     198.     344.   202.  **
** 9/12/79        400       .0    10.3      8.5     208.     351.   206.  **
** 9/12/79        500       .0    10.3      8.6     206.     348.   204.  **
** 9/12/79        600       .0    10.1      8.8     221.     366.   215.  **
** 9/12/79        700       .0     9.7      9.3     228.     364.   214.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
** 0/ 0/79          0       .0      .0       .0       0.       0.     0.  **
*************************************************************************

@FIN
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